OPERATING AND SERVICE MANUAL

MODEL 150A/AR

HIGH FREQUENCY OSCILLOSCOPE

SERIALS PREFIXED: 048 -

HP PART NO. 150A-900

HEWLETT hp PACKARD

CERTIFICATION

The Hewlett-Packard Company certifies that this instrument was thoroughly tested and inspected and found to meet its published specifications when it was shipped from the factory. The Hewlett-Packard Company further certifies that its calibration measurements are traceable to the U.S. National Bureau of Standards to the extent allowed by the Bureau's calibration facility.

WARRANTY AND ASSISTANCE

All Hewlett-Packard products are warranted against defects in materials and workmanship. This warranty applies for one year from the date of delivery, or, in the case of certain major components listed in the operating manual, for the specified period. We will repair or replace products which prove to be defective during the warranty period. No other warranty is expressed or implied. We are not liable for consequential damages.

Service contracts or customer assistance agreements are available for Hewlett-Packard products that require maintenance and repair on-site.

For any assistance contact your nearest Hewlett-Packard Sales and Service Office. Addresses are provided at the back of this manual.

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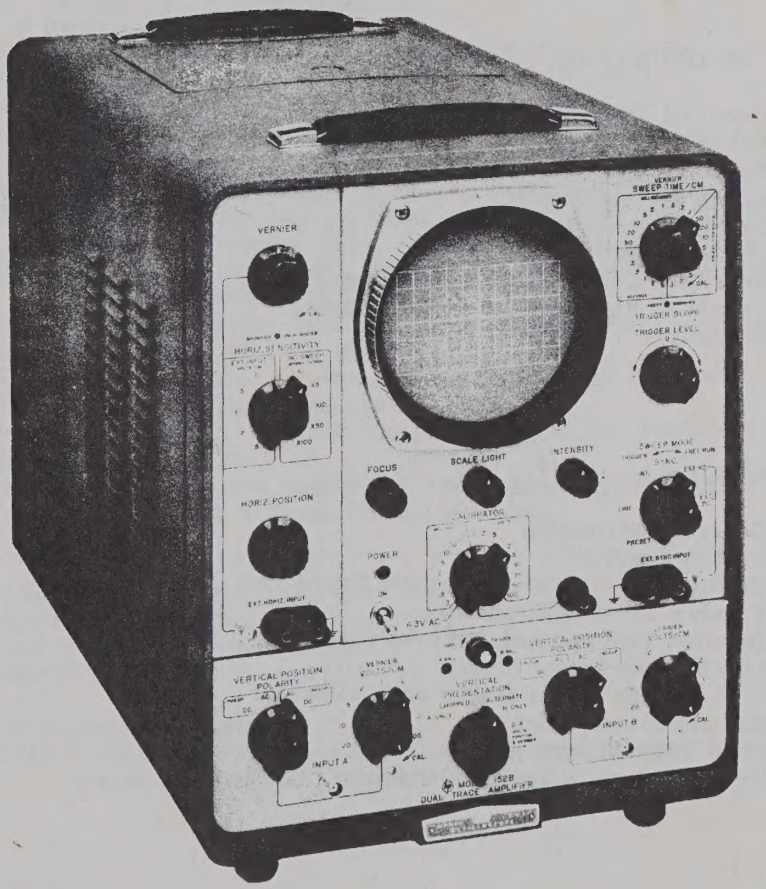

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CONTENTS

MANUAL CHANGES

MODEL 150A

OSCILLOSCOPE

Manual Serial Prefixed: 048-
Manual Printed: 1/61

Make all changes in this manual according to the Errata below: Also check the following tables for your instrument serial prefix (3 digits) and/or serial number (8 digits) and make any listed change(s) in the manual:

Serial Prefix or Number	Make Manual Changes	Serial Prefix or Number	Make Manual Changes
048-04089 to -04239	1		
048-04240 to -04364	1, 2		
048-04365 & Above	1, 2, 3		

ERRATA

Figure 4-11,
R119: Change value to 22K ohms.
Figure 4-13,
V20, 21: Change tube type to 6AH6.
R201: Change value to 390K ohms.
Table of Replaceable Parts,
C46 (only): Change description to "Same as C27"
C58: Change Mfr. to 28480 and hp Stock No. to 0140-0018.
C101: Change manufacturer's number to 56289.
C136: Change to capacitor, fixed, electrolytic, 4 sections, 20 µf/section, 450 vdcw; hp Stock No. 0180-0125; Mfr. 56289; TQ 1; RS 1.
CR5: Change to read "Rectifier, selenium; hp Stock No. 1882-0010; Mfr. 81483.
CR29 thru CR32: Change Mfr. to 28480 and hp Stock No. to 1901-0029.
I13, 14, 15: Change to lamp, neon, selected, green code; hp Stock No. 5080-0419.
R119: Change to resistor, fixed, composition, 22K ohms ±10%, 2W; hp Stock No. 0693-2231; Mfr. 01121.
R201: Change to resistor, fixed, composition, 390K ohm ±10%, 1/2W; hp Stock No. 0687-3941; Mfr. 01121.
V20, 21: Change to tube, electron, 6AH6; hp Stock No. 1923-0017; Mfr. 33173.
V49: Change manufacturer's number to 0000I.
Under V31 description, add P31 phosphor; hp Stock No. 5083-0151.
Under MISCELLANEOUS:
Jewel: small lucite (for magnifier): add hp Stock No. 150A-37A; Mfr. 28480.
Fuseholder: Change hp Stock No. to 1400-0084.

CHANGE 1

Figure 4-16 (T2 Filament Detail and Connectors),
Change secondary terminal marked F2 to read F1.
Change secondary terminal marked F1 to read F2.
Change P15-J15 Pin 1 to read P15-J15 Pin 8.

Table of Replaceable Parts,
Add S13: Switch, slide; hp Stock No. 3101-0034 (for 115/230V Operation).
See wiring diagram, Figure 1 (on page 2).

Serial Prefix or Number	Make Manual Changes	Serial Prefix or Number	Make Manual Changes
048-04089 to -04239	1		
048-04240 to -04364	1, 2		
048-04365 & Above	1, 2, 3		

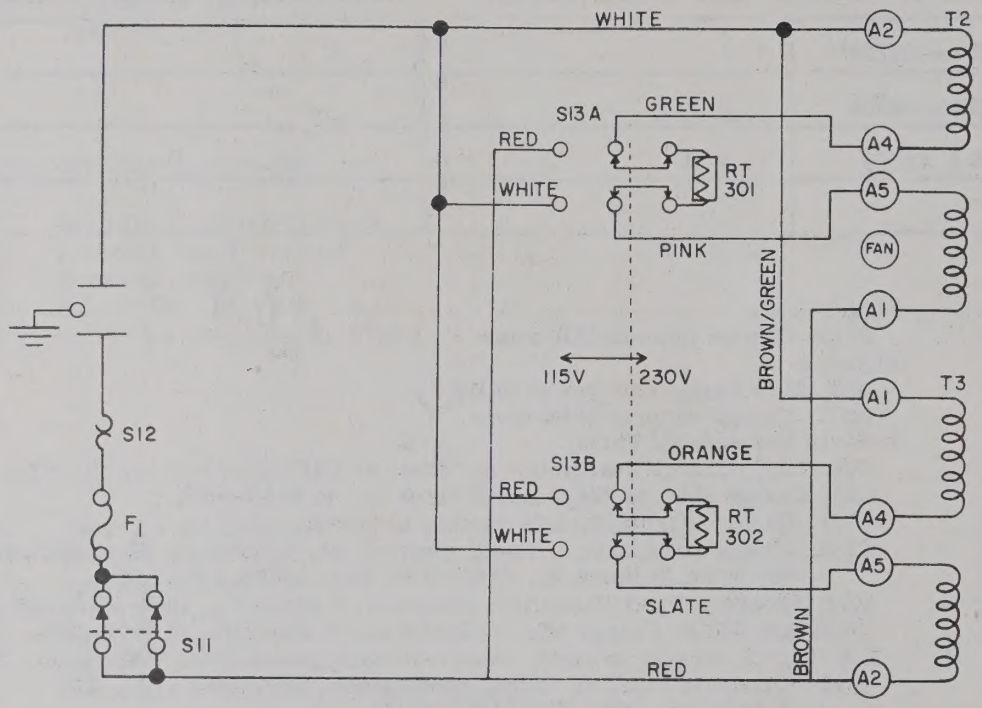


Figure 1. 115V/230V Primary Wiring Diagram

CHANGE 2

Figure 4-15 (value only) and Table of Replaceable Parts

C133, 135, 139, 142, 143, 144 and 155: Change to capacitor, fixed, paper, 0.051 µf ±10%, 400 vdcw; ℗ Stock No. 0160-0043; Mfr. 14655.

CHANGE 3

Figure 4-13 (value only) and Table of Replaceable Parts

R183, 195: Change to resistor, fixed, metal film, 196K ohms ±1%, 1/2W; ℗ Stock No. 0757-0063; Mfr. 19701.

R187: Change to resistor, fixed, metal film, 169K ohms ±1%, 1/2W; ℗ Stock No. 0757-0066; Mfr. 19701.

R196: Change to resistor, fixed, metal film, 1.4M ±1%, 1/2W; ℗ Stock No. 0757-0065; Mfr. 19701.

R198: Change to resistor, fixed, metal film, 261K ohms ±1%, 1/2W; ℗ Stock No. 0757-0064; Mfr. 19701.

— SPECIAL NOTE —

RACK MOUNT MODEL ONLY

With RACK MOUNT Model 150A's only, remove the two LARGE screws at the rear of the cabinet before installation. This permits the chassis to slide forward for servicing.

SPECIFICATIONS

SWEEP GENERATOR

INTERNAL SWEEP: 24 calibrated ranges provide sweep times from 0.1 μsec/cm to 5 sec/cm; accurate to within 3%.

A vernier control provides continuous adjustment of sweep speed between calibrated ranges and extends slowest sweep to 15 sec/cm.

MAGNIFICATION: 5 calibrated ranges; X1, X5, X10, X50 and X100 magnifies center portion of unmagnified trace, increases fastest sweep speed to .02 μsec/cm except 1 μsec X50 magnification and 2 μsec X100 magnification. X1 and X5 ranges retain accuracy of original sweep.

TRIGGERING: Internal, from line power or vertical input signal which causes 1/2 cm or more vertical deflection.

External, either capacitive or direct coupled, with 1/2V p-p or more.

TRIGGER POINT: Sweep can be triggered from either a positive or a negative going voltage; the triggering voltage level of external sync signals is continuously adjustable from -30 to +30 volts.

Switch position automatically provides optimum sync stability for majority of uses.

SINGLE SWEEP: Switch provides single-sweep operation.

SAWTOOTH OUTPUT: +20 to -20 volt sawtooth output available concurrent with sweep.

GATE OUTPUT: 20-volt positive pulse for duration of sweep.

HORIZONTAL AMPLIFIER

BANDWIDTH: Direct current to 500 kilocycles.

SENSITIVITY: 5 ranges provide sensitivities from 0.2 volt/cm to 5 volts/cm. A vernier control provides continuous adjustment between ranges and extends the minimum sensitivity to 15 volts/cm.

INPUT IMPEDANCE: 1 megohm shunted by approximately 27 pf.

VERTICAL AMPLIFIER

Used with plug-in preamplifier units. See instruction manual for particular model used.

CALIBRATOR

OUTPUT: Nominal 1000-cycle square wave having approximately 1 μsec rise and decay time available at front-panel connector.

18 calibrated ranges provide from 0.2 millivolt to 100 volts peak-to-peak, accurate to within 3%.

SPECIFICATIONS (CONT'D.)

CATHODE RAY TUBE

TYPE:	5AMP- mono-accelerator, flat face, available with P1, P2, P7 or P11 screen. 5000-volt accelerating potential.
FILTER SUPPLIED:	Compatible with phosphor, green with P1 and P2, amber with P7, and blue with P11.
GRATICULE:	10 cm long x 6 cm high marked in centimeter squares; 2 mm subdivisions on horizontal and vertical axes. Controlled edge lighting.
DEFLECTION PLATE CONNECTIONS:	Both screw and pin type terminals to receive wires or special connector assembly for connection to plates.
DEFLECTION SENSITIVITY:	20 volts/cm approximately.
INTENSITY MODULATION:	+20 volt pulse required to blank CRT trace of normal intensity.
REPLACEABILITY:	CRT bezel removes easily for replacement of graticule or for replacement of the CRT without removing the cabinet of the 150A or without removing the 150AR from the rack. CRT bezel provides firm mounting for standard oscilloscope cameras.

GENERAL

POWER REQUIREMENTS:	115/230 vac ±10%, 50/60 cps, approximately 610 watts.
DIMENSIONS:	Cabinet Mount: 14 in. wide, 17-1/2 in. high, 24-1/2 in. deep. Rack Mount: 19" wide, 15-1/2" high Depth behind panel is 23-5/16 in.
WEIGHT:	Cabinet Mount: Net 83 lbs., shipping 125 lbs. Rack Mount: Net 97 lbs., shipping 198 lbs.
PLUG-IN AMPLIFIERS:	Model 151B High Gain Amplifier, dc to 10 mc, 5 mv/cm, Model 152B Dual Trace Amplifier, dc to 10 mc, differential input, Model 153A High Gain Differential Amplifier, dc to 500 kc, 1 mv/cm. Model 154A Voltage/Current Amplifier, dc to 10 mc, 5 mv/cm; 50 cps to 8 mc, 1 ma/cm.
ACCESSORIES AVAILABLE:	Model 115B Testmobile AC-83A viewing Hood 460B-95A, Oscilloscope adapter for connecting the output of a 460B Fast Pulse Amplifier to the 150A/AR Deflection Plates. AC-21A Probe, 10:1 AC-21C Probe, 50:1 AC-21F Current Probe AC-21J Low Frequency Probe AC-67B/C Termination for AC-21F AC-76A BNC to binding post adapter
ACCESSORIES FURNISHED:	Two AC-21A Probes. Two AC-76A BNC to binding post adapters.

SECTION I
GENERAL DESCRIPTION

1-1 GENERAL INFORMATION

The Model 150A dc to 10 mc oscilloscope is a general purpose oscilloscope employing a 5AMP- mono-accelerator type cathode ray tube with unitized, plug-in construction for maximum accessibility and flexibility. It can be used with either internal or external sweeps which can be either internally or externally synchronized. The horizontal amplifier incorporates magnification circuitry which is capable of expanding basic internal sweeps up to 100 times. The internal sweep range extends from .02 μsec/cm to 15 sec/cm.

The Model 150A uses a variety of vertical amplifier plug-in units to perform different functions. The various plug-in amplifiers available are described in the table of specifications.

Since operation of the rack model is similar to that of the cabinet model, the operation of the instrument will be described without regard to style of mounting.

1-2 DAMAGE IN TRANSIT

Should any shipping damage become evident refer to the "Claim for Damage in Shipment" paragraph on the warranty sheet in this manual.

1-3 POWER LINE VOLTAGES

The Oscilloscope is shipped from the factory wired for 115 volt ac line operation, unless otherwise specified. However, the instrument may also be operated from a 230 volt ac line source if the proper conversion is made to the power transformer. This conversion is described in the Maintenance Section (Section IV).

1-4 POWER CORD

The three conductor power cable supplied with the instrument is terminated in a polarized three prong male connector recommended by the National Electrical Manufacturers' Association. The third contact is an offset round pin, added to a standard two-blade ac plug, which grounds the instrument chassis when used with the appropriate receptacle. An adapter should be used to connect the NEMA plug to a standard two contact output. When the adapter is used, the ground connection becomes a short lead from the adapter which should be connected to a suitable ground for the protection of operating personnel.

On the rack mount Model 150AR, the instrument is connected to the ac receptacle in the cabinet by means of a retracting coil cord. This permits the instrument to slide out of the cabinet while still in operation.

1-5 COOLING

The Model 150A employs a forced draft cooling system to maintain satisfactory operating temperatures within the case. The air intake and filter are located under the instrument case, and adequate cooling will take place as long as the case is on the instrument and nothing obstructs the filter. Generally, the height of the cabinet feet provides such clearance. Thus, the Model 150A can be used in a confined bench set-up as long as the underside of the cabinet is clear, and ambient temperatures are not extreme.

1-6 OVERLOAD RELAY

The Model 150A has an overload relay which interrupts operation when:

1. Any series tube on the regulated dc heater string is removed while the instrument is on.
2. A plug-in vertical amplifier is removed while the instrument is on.
3. A short circuit or excessive loading of any positive-voltage supply occurs.

To reset the overload relay remove the cause, and turn the instrument off for one minute or more. The instrument may then be turned on again and operated normally.

SECTION II
OPERATING INSTRUCTIONS

2-1 INSTRUMENT SAFETY DEVICES

The Model 150A contains circuits which delay the application of dc operating voltages for approximately 30 seconds. This delay allows all tube heaters to reach operating temperature before power is applied to the instrument. In addition, protective relays are provided which disconnect the dc operating voltages when overloads or other potentially dangerous conditions occur. When the instrument is turned off these circuits require at least one minute to re-cycle. For this reason you should always wait at least one minute after turning the power switch off before turning it back on. If you do not allow adequate time the protective relays will lock out the operating voltages and the instrument will not come on. The protective circuits will operate whenever the plug-in amplifier, or any tube with a regulated dc heater supply is disconnected when the unit is turned on.

In addition this instrument is provided with a thermal cutout switch which opens the main power circuit if the internal temperature exceeds a safe value. If the instrument has been operating and suddenly goes off, the cutout may have operated. Remove the cause of the overheating and reset the cutout shown in Figure 2-9.

2-2 CONTROLS AND TERMINALS

The controls and terminals of both the cabinet and rack models operate identically. The controls and terminals of the central section of the rack mount model front panel are the same as those on the panel of the cabinet model. However, the controls and terminals inside the access hatch in the cabinet model are mounted on the front panel in the rack mount model. Directions in this book refer to both models unless otherwise specified.

The illustrations at the back of this section explain the operation of the controls and terminals for the various methods of operation. If the instrument does not function properly, refer to the Maintenance Section in this manual.

CAUTION

Turn the INTENSITY control to minimum before turning on the instrument and when the unit is not in actual use. Excess intensity, particularly with only a spot on the screen, can rapidly damage the cathode ray tube screen.

2-3 VERTICAL AMPLIFIERS

Vertical amplifiers for the Model 150A are built in the form of plug-in units for the bottom section of the oscilloscope. This permits selection of the proper vertical amplifier for a particular purpose. See the instruction manual for the particular plug-in amplifier in use for operating information.

2-4 AC OR DC COUPLING

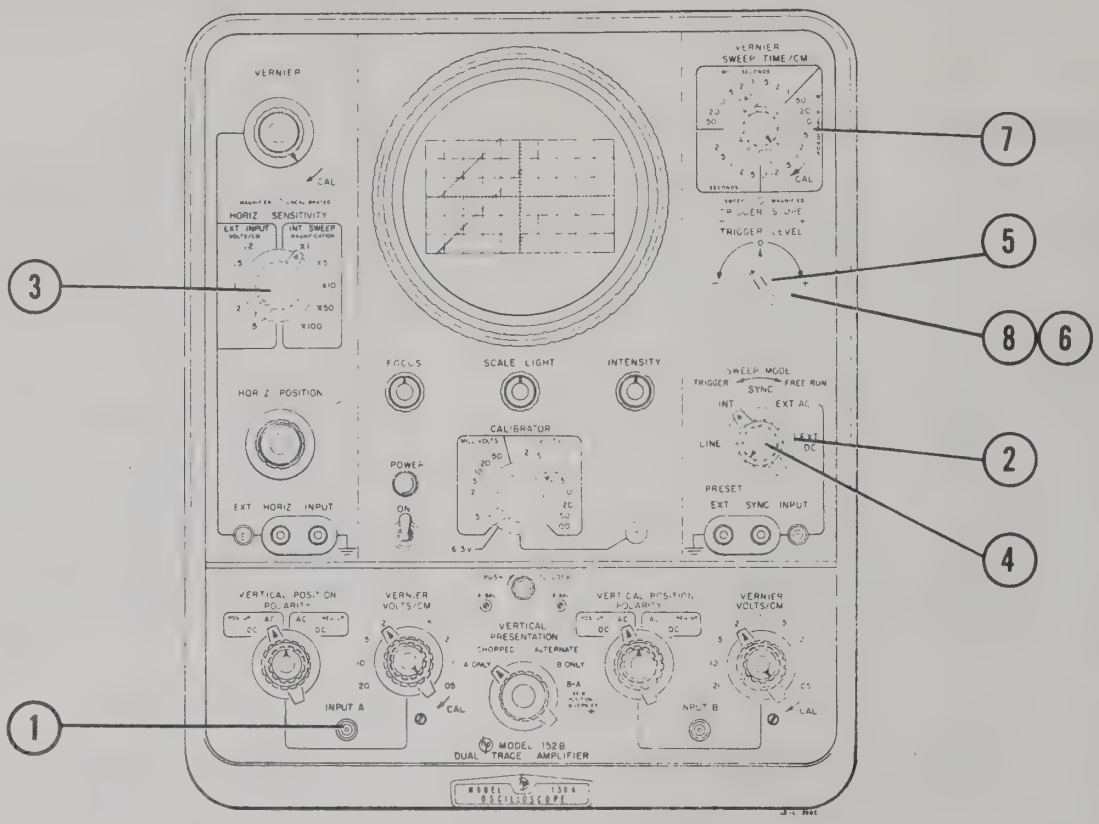
Under most conditions ac coupling will be used. It permits high gain to be employed without regard for the dc levels involved. In the AC position the input signal (vertical or external sync) is coupled to the instrument through a capacitor which removes the dc component from the input wave. Because of the low frequency cut-off of this circuit it is advisable to use dc coupling to view complex waves below approximately 200 cps. Use dc coupling to look at waveforms relative to a dc level. WHEN USING DC COUPLING THE POSITION OF THE TRACE ON THE SCREEN IS DETERMINED BY THE DC LEVEL. IF THE TRACE CANNOT BE ADJUSTED TO PLACE IT ON THE SCREEN, CHECK THE LEVEL TO DETERMINE IF THE INPUT STAGES ARE OVERLOADED.

2-5 AC-21A LOW-CAPACITY PROBE

The probe's alligator-clip jaws are opened by squeezing together the flanges on the probe body.

Typical step-by-step instructions for adjusting the probe for flat response are presented in Figure 2-5.

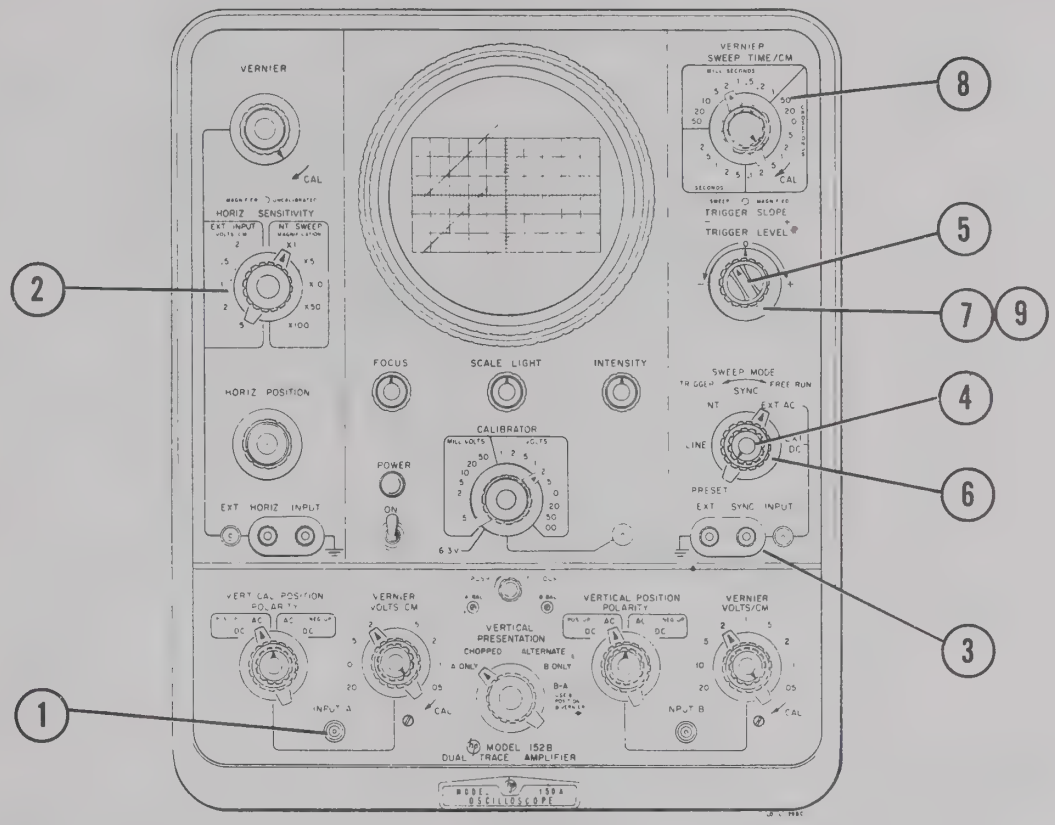
INTERNAL SWEEP—INTERNAL SYNCHRONIZATION



1. Connect vertical input signal to the plug-in amplifier.
2. Set SYNC selector to INT.
3. Set HORIZONTAL SENSITIVITY to INT SWEEP Xl.
4. Set SWEEP MODE to PRESET.
5. Set TRIGGER SLOPE for triggering on positive or negative slope, as desired.
6. Set TRIGGER LEVEL to 0.
7. Select desired sweep speed with SWEEP TIME/CM switch.
8. Adjust TRIGGER LEVEL to start trace at desired level. In some cases, it may be necessary to switch SWEEP MODE from PRESET to an individual adjustment for the particular trace being viewed.

Figure 2-1

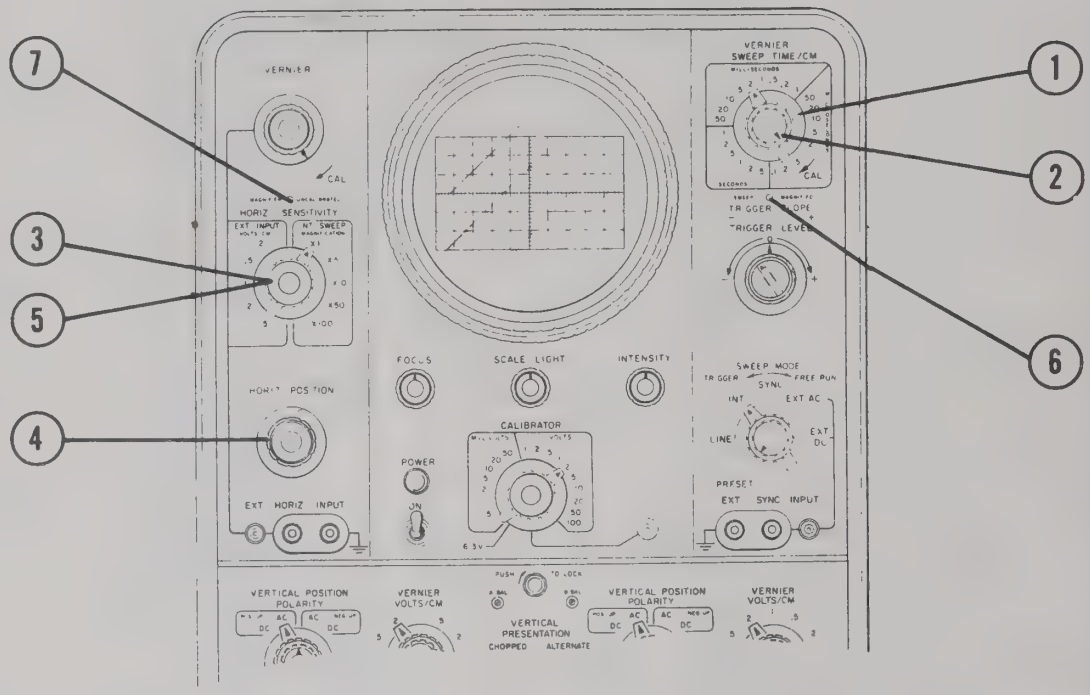
INTERNAL SWEEP - EXTERNAL SYNCHRONIZATION



1. Connect vertical input signal to the plug-in amplifier.
2. Set HORIZ SENSITIVITY to INT SWEEP X 1.
3. Connect external sync signal to EXT SYNC INPUT terminals.
4. Set SWEEP MODE to PRESET.
5. Set TRIGGER SLOPE for triggering on positive or negative slope, as desired.
6. Set SYNC selector to EXT AC or EXT DC, as required.
7. Set TRIGGER LEVEL to 0.
8. Select desired sweep speed with SWEEP TIME/CM switch.
9. Adjust TRIGGER LEVEL to start trace at desired level. In some cases it may be necessary to switch SWEEP MODE from PRESET to an individual adjustment for the particular trace being viewed.

Figure 2-2

INTERNAL SWEEP MAGNIFICATION



1. Select sweep speed with SWEEP TIME / CM switch.
2. Set VERNIER in CAL when direct reading of SWEEP TIME/CM switch is desired.
3. Set HORIZ SENSITIVITY to INT SWEEP X1 (X1 is the unmagnified sweep position.)
4. Adjust horizontal position of trace. To magnify a portion of a wave or a particular wave in a train, place it under vertical graticule center line with HORIZ POSITION control.
5. Switch HORIZ SENSITIVITY to desired magnification (X5 or above).
6. SWEEP MAGNIFIED indicator will light.
7. If combination of sweep speed and degree of magnification exceeds maximum calibrated sweep speed (.02 μseconds/cm) the MAGNIFIER UNCALIBRATED indicator will light.

EXAMPLE

SWEEP TIME/CM = .5 μsec/CM
MAGNIFICATION = X50

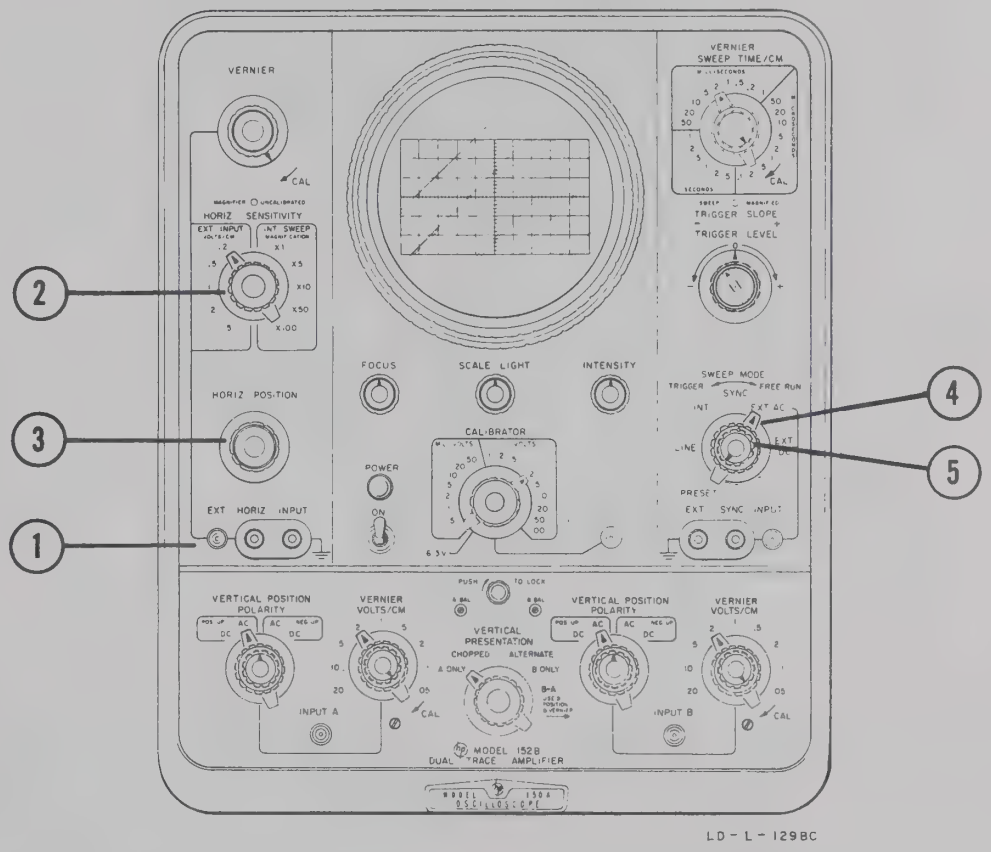
Actual sweep time/cm = .5 μsec/cm ÷ X50 = .01 μsec/cm. Uncalibrated lamp will light. Increase sweep time or reduce degree of magnification.

SWEEP TIME/CM = .5 μsec/CM
MAGNIFICATION = X10

Actual Sweep Time = .5 μsec/cm ÷ (X10)
= .05 μsec/cm
(Sweep time > .02 μsec/CM, MAGNIFIER UNCAL lamp stays off).

Figure 2-3

EXTERNAL HORIZONTAL INPUT

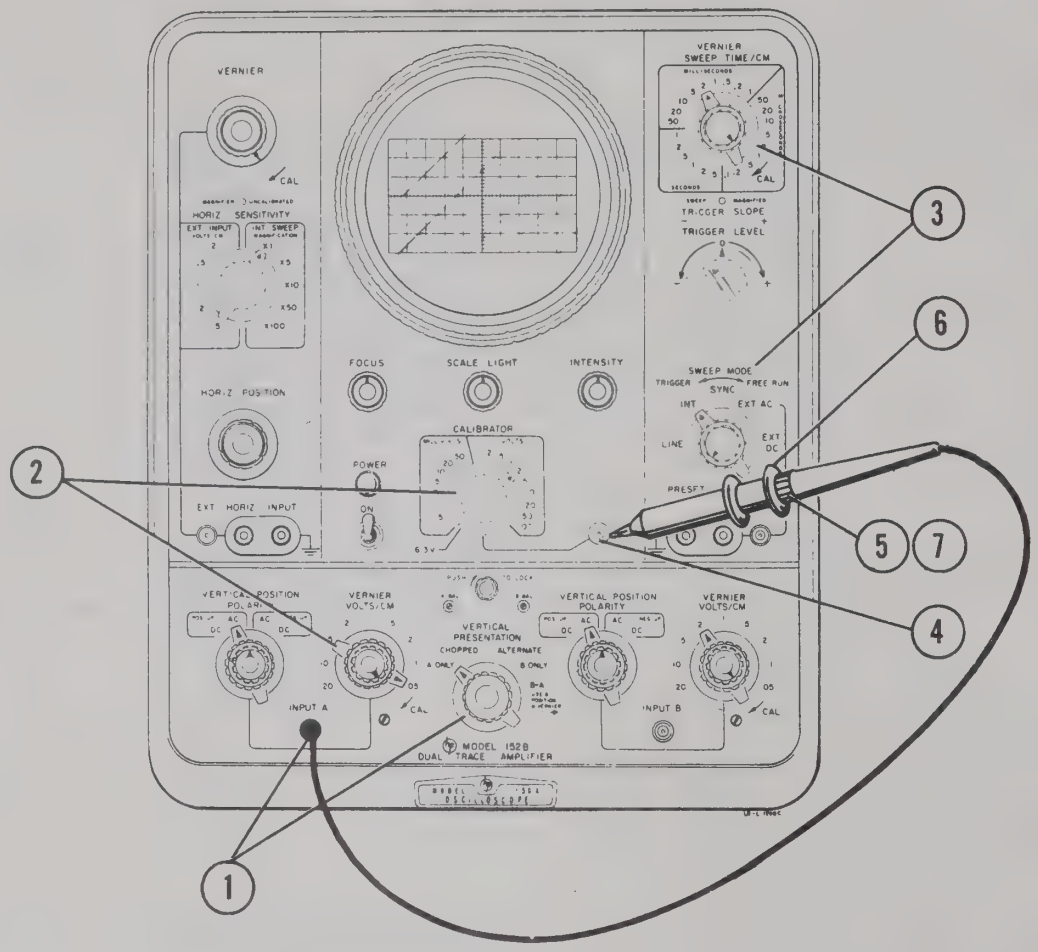


LD-L-129BC

1. Insert external horizontal signal.
2. Select desired sensitivity on EXT. INPUT of HORIZONTAL SENSITIVITY control.
3. Adjust horizontal position.
4. Turn SYNC selector to an EXT. position.
5. Set SWEEP MODE just off PRESET.

Figure 2-4

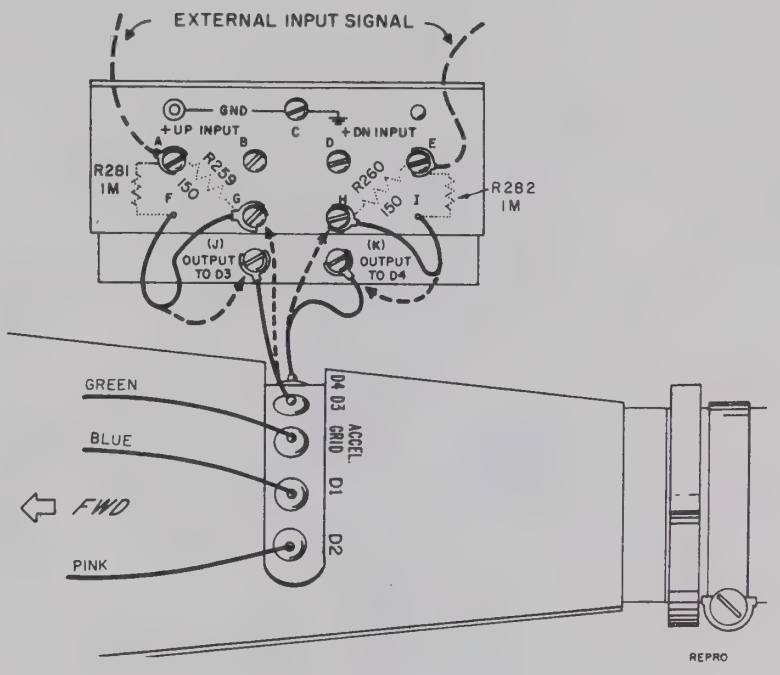
ADJUSTING AC 21A LOW CAPACITY PROBE



1. Connect the AC-21A Probe to the desired vertical input, and set the VERTICAL PRESENTATION selector to the corresponding input.
2. Set the CALIBRATOR selector to 2v. Set the vertical VOLTS/CM selector to .05.
3. Set the SWEEP TIME/CM selector to .5 MILLISECOND/CM; set the SYNC selector to INT; the SYNC control to PRESET.
4. Touch the probe to the CALIBRATOR connector and observe the 1-kc square wave.
5. Loosen probe locknut by unscrewing.
6. Adjust probe to obtain flattest top on square wave by turning rear flange on probe.
7. Tighten locknut to retain adjustment.

Figure 2-5

DIRECT CONNECTION TO DEFLECTION PLATES



CAUTION - The deflection plates of the oscilloscope operate at a d-c potential of approximately +250 volts. Therefore, there can be no common chassis connection between the signal source and the oscilloscope. In most cases the signal source chassis will assume the deflection plate potential. Turn off the instrument before making connection to deflection plate terminals.

To connect an external signal directly to vertical deflection plates:

A. Balanced Input

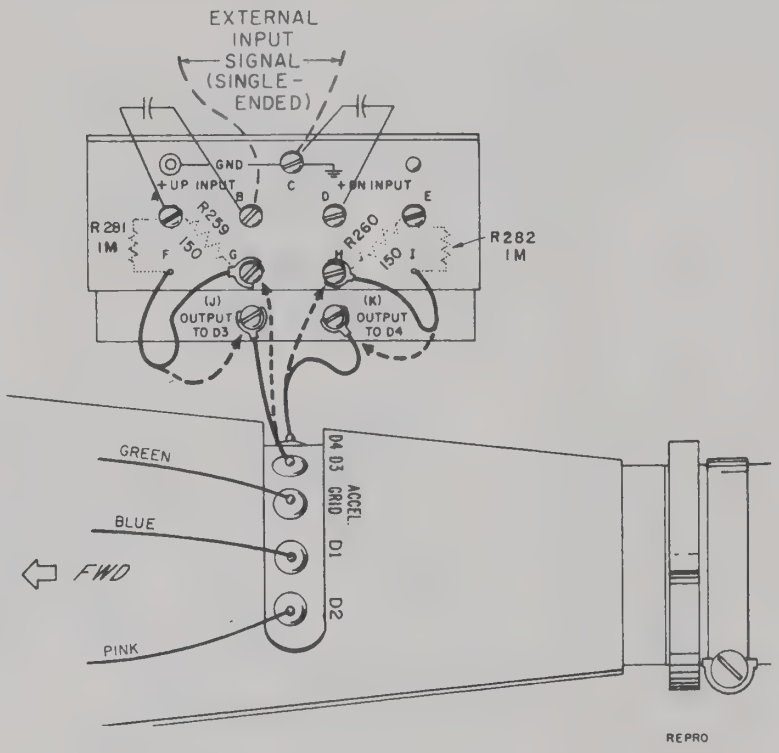
1. Connect signal to terminals A and E.
2. Relocate leads from F, I, D3 and D4 as shown by dashed lines.

B. Single-Ended Input

1. Connect the signal to A for + up deflection (to E for + down deflection).
2. Connect an appropriate bypass capacitor between C and E for + up deflection (between C and A for + down deflection). Signal source return connects to E or A, whichever is bypassed.
3. Relocate leads from F, I, D3 and D4 as shown by dashed lines.

Figure 2-6

CAPACITIVE CONNECTION TO DEFLECTION PLATES



CAUTION - Turn off instrument before making connection to deflection plate terminals.

To ac couple a signal to the vertical deflection plate:

A. Single-Ended Input

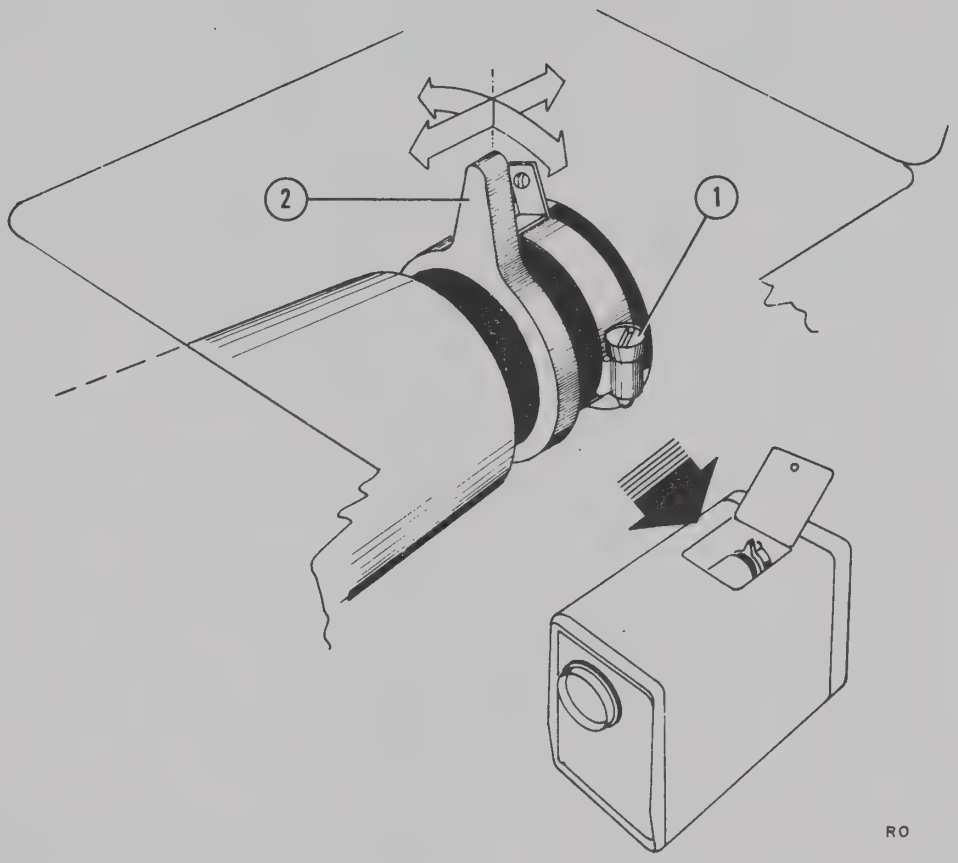
1. Connect external signal to B for + up deflection (to D for + down deflection) and the signal return to C.
2. Connect an appropriate bypass capacitor between C and E for + up deflection (between C and A for + down deflection).
3. Connect an appropriate d-c blocking capacitor between A and B for + up deflection (between D and E for + down deflection).
4. Relocate leads from F, I, D3, and D4 as shown by dashed lines.

B. Balanced Input

1. Connect external balanced signal to terminals B and D.
2. Connect appropriate d-c blocking capacitors between terminals A and B and between terminals D and E.
3. Relocate leads from F, I, D3, and D4 as shown by dashed lines.

Figure 2-7

ALIGNING SCOPE TRACE WITH GRATICULE

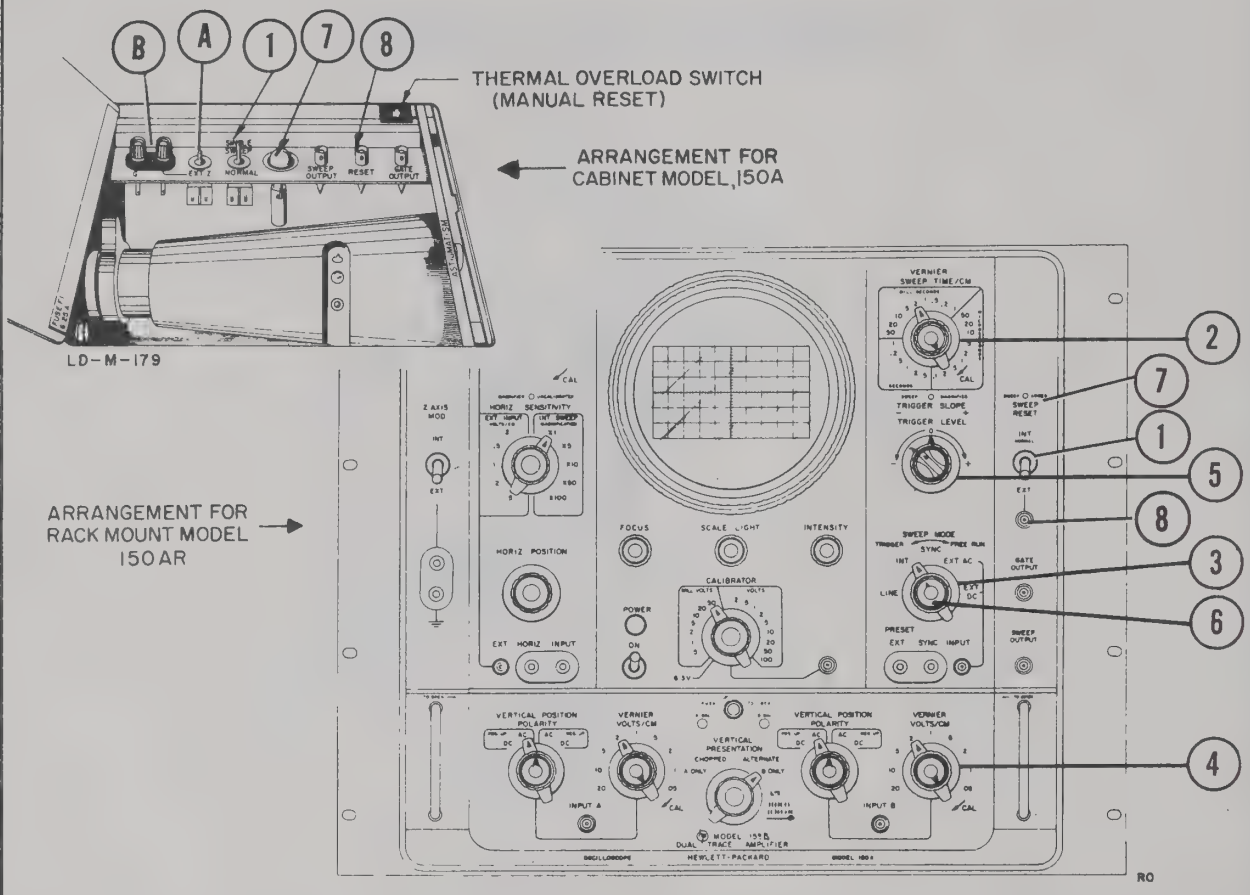


ALIGNMENT OF CATHODE RAY TUBE

Lever (2) controls both radial and longitudinal positioning of CRT and is locked by clamp (1).

Figure 2-8

SINGLE SWEEP AND INTENSITY MODULATION OPERATION



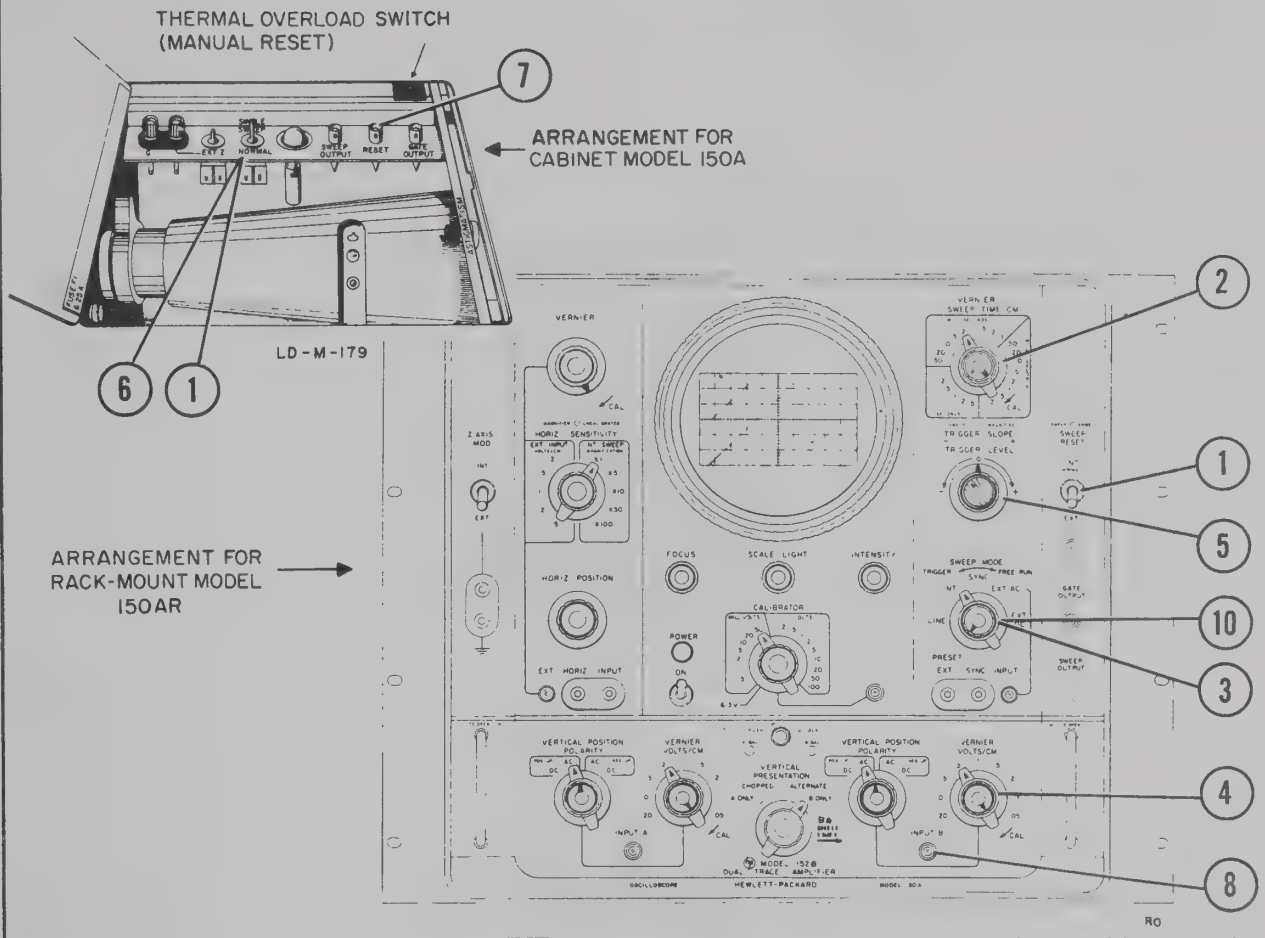
1. Set selector switch to SINGLE or EXT. sweep.
2. Select sweep speed.
3. Set SYNC switch to INT. and SWEEP MODE to PRESET.
4. Select desired vertical sensitivity.
5. Adjust TRIGGER LEVEL to ZERO and SLOPE as desired. (In some applications it may be convenient to establish desired TRIGGER LEVEL in NORMAL operation.)
6. Switch SWEEP MODE control out of PRESET and back to PRESET to arm sweep circuit.
7. Indicator should light as soon as SWEEP MODE control is returned to PRESET. When input signal is received, sweep will fire once, indicator (7) will extinguish, and sweep will remain locked out until reset as described in step 6; or
8. Resetting can be accomplished by placing 1-200 μsec width, +12 to +18 volts peak pulse into RESET terminal.

To intensity modulate the CRT with external signals:

a) Set INT. Z - EXT. Z switch to EXT. Z.
b) Connect modulating signal to input terminals. A positive voltage of 20 volts peak will blank the CRT trace from normal intensity. A negative input will brighten the trace.

Figure 2-9

DELAYED SWEEP OPERATION



1. Set selector switch to NORMAL or INT.
2. Select sweep speed.
3. Set SYNC switch to INT and SWEEP MODE to PRESET.
4. Select desired vertical sensitivity.
5. Adjust TRIGGER LEVEL and SLOPE for desired triggering.
6. Set selector switch to SINGLE SWEEP.
7. Connect output of DELAY GENERATOR to RESET terminal inside top access hatch.
8. Connect signal to be observed to scope input.
9. Connect trigger source to input of delay generator. Trigger-source signal in some applications may be same as signal to be observed (step 8) or it may be some other signal. This signal serves as a single sweep retriggering source. (See SINGLE SWEEP OPERATION.)
10. It may be desired to have the sweep start immediately at end of delay period instead of awaiting the arrival of signal to be observed. To accomplish this, follow steps 1 through 9, except that after step 6, set SWEEP MODE control to FREE RUN.

Figure 2-10

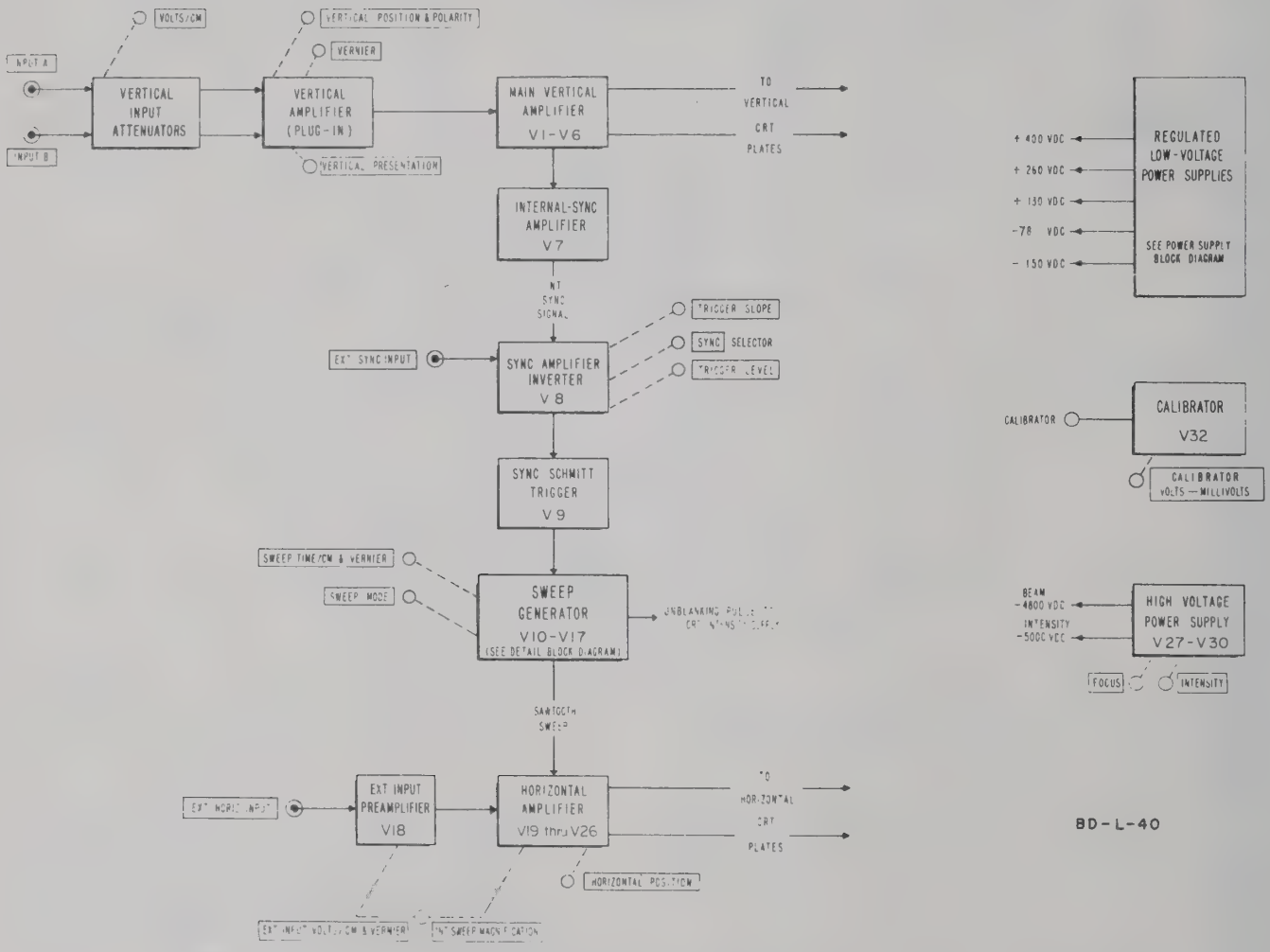


Figure 3-1. Block Diagram Complete Oscilloscope

SECTION III
THEORY OF OPERATION

3-1 OVER-ALL OPERATION

The block diagram in Figure 3-1 shows the basic signal circuits in the Model 150A Oscilloscope: the Vertical Amplifier, Horizontal Amplifier, Sweep Generator and Cathode Ray Tube.

a. Vertical Amplifier - The complete vertical amplifier receives the input signal, amplifies it, and drives the vertical deflection plates. It provides attenuation of the input signal if necessary; determines the direction of spot deflection for a given input signal polarity; determines the vertical position of the spot on the screen; supplies a signal for internal synchronization; and incorporates a 0.25 μsec delay in the input waveform.

The complete Vertical Amplifier circuit is in separate parts: first the input attenuators, phase inverter, vertical position controls and amplifiers in the Vertical Amplifier Plug-In Unit, and second the intermediate and final amplifiers on the instrument chassis.

b. Horizontal Amplifier - The horizontal amplifier is driven either from the HORIZONTAL INPUT jack or from the internal sweep generator.

The complete Horizontal Amplifier consists of the main amplifier, and a preamplifier (used only for external signals applied to the HORIZONTAL INPUT connector). The preamplifier stage includes the VOLTS/CM portion of the HORIZONTAL SENSITIVITY selector switch and is not in use when the switch is set to one of the MAGNIFICATION positions. The MAGNIFICATION circuit of the HORIZONTAL SENSITIVITY selector is in the Main Horizontal Amplifier. The sawtooth sweep is applied directly to the Main Horizontal Amplifier while external signals are first applied to the HORIZONTAL SENSITIVITY switch and the preamplifier.

c. Sync Circuit - The Synchronizing Circuit receives a signal either from the Vertical Amplifier for internal synchronization, from the EXT. SYNC INPUT or from an internal power line source. The Sync Circuit amplifies all input signals, and determines the level and polarity which will start a sweep.

d. Sweep Generator - The Sweep Generator starts on receiving a sync pulse from the Sync Circuit and generates a sawtooth to drive the Horizontal Amplifier. The Feedback Integrator determines the basic sweep time per centimeter, and the SWEEP MODE control selects triggered or free-running operation. A SINGLE SWEEP switch provides either single or repetitive sweeps. The sweep generator also supplies unblanking pulses to the CRT, a timing signal (during each sawtooth flyback) to the Dual Channel Vertical Amplifier Plug-In Unit for ALTERNATE operation, and sweep and gate signals to output connectors.

e. The CRT - The CRT is a type 5AMP- mono-accelerator tube with the cathode operated at -4800 volts. The mono-accelerator anode makes possible a simple astigmatism adjustment (located inside the access hatch) which requires no resetting when adjusting the FOCUS or INTENSITY. The deflection plate terminals located on the periphery of the tube neck are connected through removable jumpers directly to the Main Vertical Amplifier, Horizontal Amplifier, and Astigmatism control.

3-2 VERTICAL AMPLIFIER

The signal from the plug-in vertical amplifier is coupled through the left-hand connector on the plug-in unit chassis to the Main Vertical Amplifier on the instrument chassis.

Input amplifiers V1 and V2 provide a maximum gain of approximately 20 db. The gain adjustment potentiometer R5, varies the degeneration in the cathode circuit of V1 and V2. It has a range of approximately 4 db.

The signals from V1 and V2 are coupled through two 0.25 microsecond delay lines (one in each side of the amplifier) to the final amplifier stages. Each delay line consists of a 25-inch length of RG-176/U coaxial cable. A compensated coupling network is used with the delay lines to maintain transmission from dc to considerably over 10 megacycles with a uniform 6 db loss.

The gain of output amplifiers V6 and V7 is approximately 16 db. Capacitor C8 is used to adjust the high frequency response of the amplifier.

3-3 HORIZONTAL AMPLIFIER

Horizontal deflection signals are selected either from the EXT. HORIZ. INPUT preamplifier or from the Sweep Generator by the HORIZ. SENSITIVITY selector and are then coupled to the grid of V20 through frequency-compensated voltage dividing networks. V20 and V21 are the two sides of a push-pull amplifier. The phase inverted signal for V21 is obtained from phase inverter V19.

The MAGNIFICATION and VOLTS/CM positions of the HORIZ. SENSITIVITY selector determine the horizontal deflection sensitivity by inserting input attenuators and adjusting the degeneration in the common cathode circuit of V20 and V21.

The push-pull signals from V20 and V21 are direct-coupled through Cathode Follower Drivers V22A and B to the Output Amplifiers V23 and V24. The Output Amplifiers contain negative feedback paths between their plates and the grids of the driving cathode followers V22A and B.

The signals from the Output Amplifiers are coupled through Output Cathode Followers V25A and B to the horizontal deflection plates. The Capacitance Drivers V26A and B improve the performance of the Output Cathode Followers during negative-going portions of the output waveform.

Breakdown diodes are used in the grid circuits of V19B, V23, and V24 to provide direct coupling without loss of signal amplitude. The breakdown diodes are returned to -150 volts through a value of resistance that assures reliable operation. A small bypass capacitor assures good coupling at high frequencies.

3-4 SYNCHRONIZING CIRCUIT

The Synchronizing Circuits consist of an Input Amplifier-Phase Inverter (V8) and a Schmitt Trigger wave shaper (V9). V8 receives synchronizing signals either from the EXT. SYNC INPUT connector on the panel, the Main Vertical Amplifier, or from the line frequency; as selected by the SYNC selector switch. The desired polarity of sync signal that is to be used to start the sweep is then taken from the appropriate plate by the TRIGGER SLOPE control.

Positive input sync signals are taken un-inverted from the plate of V8B while negative input signals are taken inverted from V8A.

The TRIGGER LEVEL control shifts the level of the amplified sync signal applied to the next stage, a trigger generator.

On receiving a positive waveform of suitable amplitude from V8, the Sync Schmitt Trigger V9, generates a negative spike for the following circuits. Adjustments are provided for centering the hysteresis limits of the trigger circuit around the zero input voltage level.

3-5 SWEEP GENERATOR

Tubes V10 through V17 produce the sawtooth sweep voltage when triggered by the synchronizing circuit.

A Schmitt trigger, V10A, produces a positive gate when a negative spike from the Sync Schmitt Trigger, V9, drives it through its lower hysteresis limit. This gate opens the Integrator Switch, V13A, and turns on the CRT beam through cathode followers V11A, V12A, and V11B.

When V13A opens, the timing capacitor starts charging toward approximately +130 volts through a timing resistor. These timing components are selected by the SWEEP TIME/CM switch. Since V14 and V15A comprise a direct coupled Miller Integrator, a very linear negative going ramp is produced by V15A which appears at the sweep output terminal.

The sweep is terminated by coupling the sweep voltage back to the grid of V10A through V16A, an inverter, and V17A and B, cathode followers. When the sweep voltage at the grid of V10A reaches the

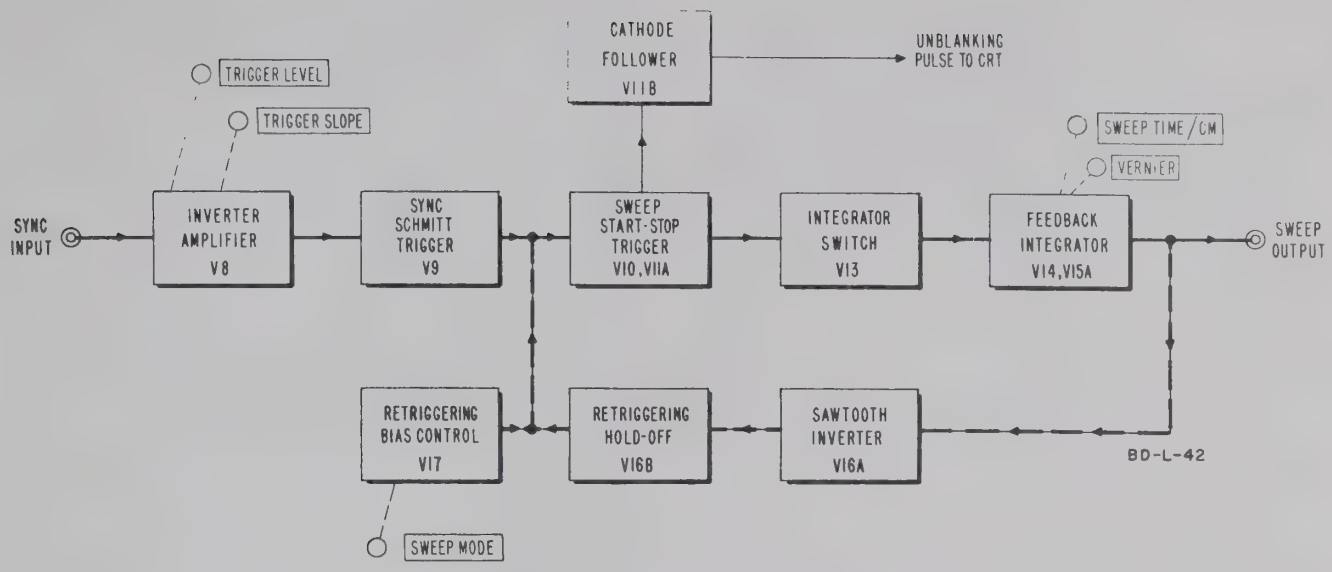


Figure 3-2. Block Diagram Sweep Circuits

upper hysteresis limit of the Schmitt Trigger V10, the positive gate is terminated and the integrator switch V13A closes, ending the sweep. This action takes place when the sweep output voltage reaches approximately -115 volts.

During the retrace, the timing capacitor charges toward -150 volts through R89. DC feedback around V14 and V15B, through V13A and B returns the sweep output voltage to the starting point. A stretching circuit in the cathode of V16B prevents the sweep from being retriggered until the Miller Integrator has completely recovered.

After the sweep is terminated, the stretched and inverted re-trace waveform is combined in V17 with the dc level selected by the SWEEP MODE control or the Preset Adjustment. Thus when the Miller Integrator has recovered to its initial condition, V10 is again ready to be triggered by a sync pulse from V9.

3-6 SINGLE SWEEP OPERATION

For SINGLE SWEEP operation, S4 converts V17 to a Schmitt trigger circuit, and ties the cathode of V17A, V17B, and V16B together. When the sweep generator is in the armed condition, the SWEEP MODE control is normally in the PRESET position; V17A is conducting, V17B is cutoff and indicator lamp I6 is lit. Then the next negative sync pulse from Schmitt Trigger V9 will start a sweep. Once triggered, the sweep cannot be re-triggered, since the output of Sync Schmitt Trigger V9 is insufficient to overcome the lock-out bias produced by the V17 Schmitt circuit. To arm the sweep circuit so that it can again be triggered by V9, it is necessary to switch conduction from V17B back to V17A (at which time indicator lamp I6 will light). This can be done manually by rotating the SWEEP MODE control away for PRESET and back again, or it can be done electrically by applying a re-setting pulse to the RESET connector inside the top access door (on the front panel in the rack model).

Two methods of electronic-reset operations are possible. The normal method, obtained with the SWEEP MODE control set to PRESET, provides a sweep triggered by the first vertical signal to occur after the reset pulse. Then the display is not affected by jitter between the reset trigger and the signal under observation. The other method, obtained with the SWEEP MODE control in FREE-RUN, starts a sweep instantaneously after the reset pulse, regardless of the presence or absence of vertical signals.

3-7 REGULATED LOW-VOLTAGE POWER SUPPLY

The complete low-voltage power supply shown in Figure 3-3 provides five regulated voltages.

The outputs from the rectifiers which supply the three positive-voltage supplies are stacked in

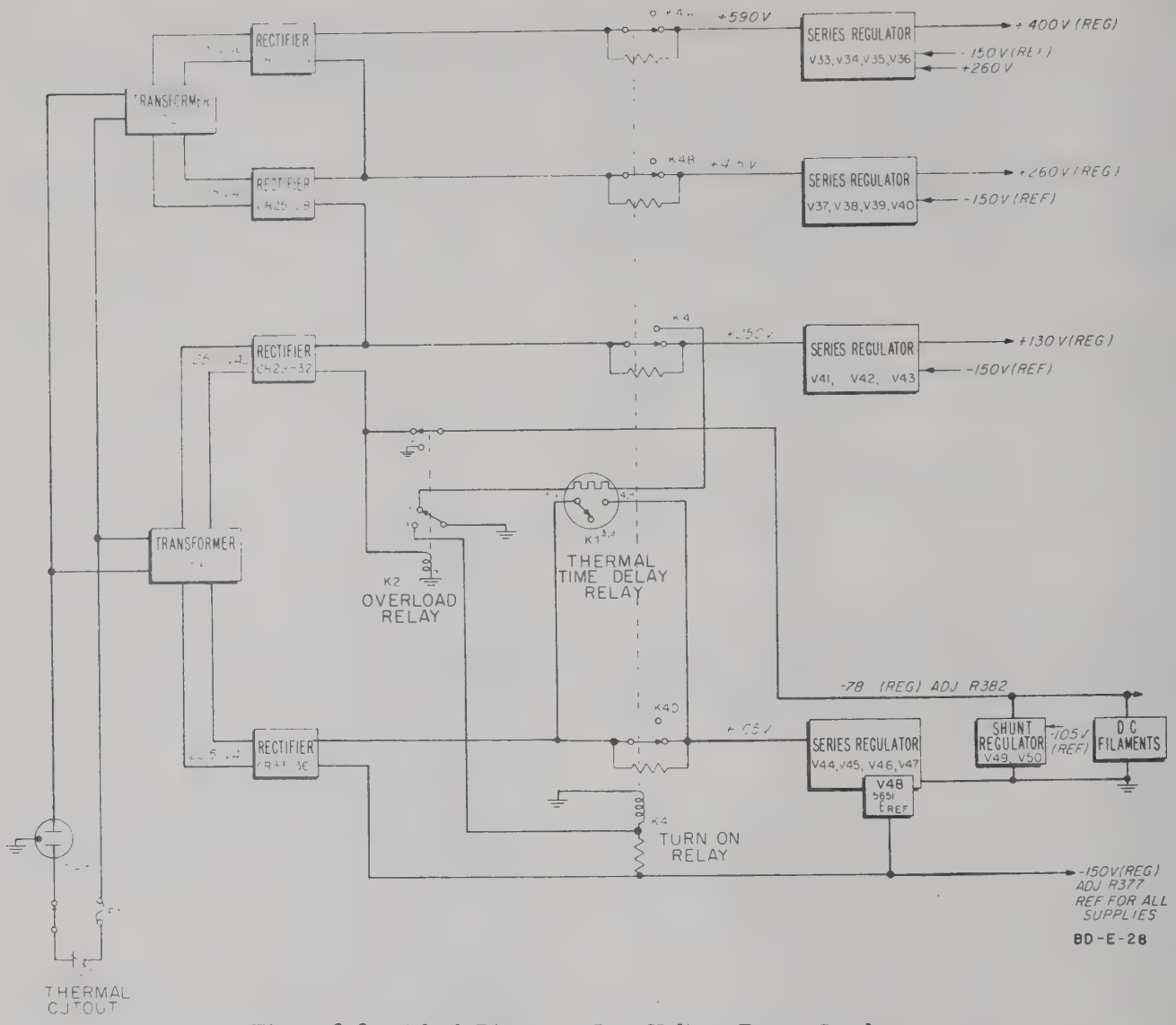


Figure 3-3. Block Diagram Low Voltage Power Supply

series. The total current of the three positive-voltage regulated supplies is sufficient to supply a series dc heater circuit. The shunt regulator, V50, controlled by V49, holds the voltage applied to the dc heater string constant.

The operation of each of the four regulated-voltage supplies is conventional. The -150 volt supply acts as a reference for the others. Three of the Control Tubes, V40, V43 and V47, have heaters supplied from the regulated dc supply.

In the complete Low Voltage Power Supply there are four protective switches of which two are dc relays, one is a thermal time delay switch and one is a temperature actuated switch. Relays K1 (Thermal Time Delay), K4 (Turn on), and K2 (Overload) protect the instrument from damage due to excessive voltages during the turn on period or from excessive current or voltage because of an overload, or a short or open circuit. Should the fan fail, the filter become clogged, or ambient temperature rise, S12 will shut off the instrument when the operating temperature at S12 reaches approximately 150°F.

Figure 3-3 is a block diagram of the Low Voltage Power Supply showing these relays and Overload

Relay K2 in the normal operating position. When power is first applied to the instrument, K4 is not energized and its contacts are in the upper position. Input voltage into the series regulators is effectively reduced by the series resistors and K1 receives heater voltage from the input to the +130 volt regulator. The same current temporarily flows to the tubes in the regulated dc heater circuit so that these tubes will be ready to operate by the time relay K1 closes. When relay K1 closes and allows the -150 volt supply to come up to full output, relay K4 is energized. Actuating K4 shorts out the resistors in series with the other supplies and permits their outputs to rise to normal operating values. Contacts K4C remove the heater voltage from Thermal Time Delay Relay K1, permitting it to cool and its contacts to open. Contacts K4D short the series resistor in the -150 volt supply, so the cooling of K1 does not interrupt the -150 volts supply. However, once K1 has cooled, any interruption of ac power or of the -150 volt output de-energizes K4 and thus lowers all regulated output voltages until the time delay cycle is completed again.

Overload Relay K2 is energized whenever the dc heater voltage exceeds -110 volts. Since this voltage is dependent upon the current from the three positive voltage rectifiers (less the current control range of the shunt regulator) an excessive current from any positive supply will trip overload relay K2. K2 operates by de-energizing K4 to lower the voltage output of the series regulators as previously explained; by disconnecting the Shunt Regulator and the dc heater circuit; and during warm-up, removing excitation voltage from the heater of K1.

With K2 energized and K4 de-energized, the small residual currents from the positive supplies flow through K2, keeping it energized. Filter capacitors in the power supply keep K2 energized for several seconds after ac power is removed from the instrument.

3-8 REGULATED HIGH-VOLTAGE POWER SUPPLY

The cathode of the CRT in the 150A is operated at -4800 volts, and the intensity grid at approximately -5000 volts. Both voltages are obtained from a high voltage supply with two independent transformer secondary windings and rectifiers, energized by a single oscillator, V27, in the primary. The cathode supply is regulated by control amplifier V28. This amplifier determines the power output of the oscillator by controlling screen voltage of V27.

Both positive and negative pulses are required simultaneously for unblanking purposes. The fast-rising positive-going pulse is taken from the cathode of V11, while the slow-rising negative-going pulse is taken from the plate.

The positive pulse is applied through a capacitor to the grid of the Cathode Ray Tube. Since this pulse is ac coupled, it cannot keep the Cathode Ray Tube unblanked. The negative unblanking pulse furnishes a direct coupled error signal to the high voltage oscillator. This causes the output of the grid supply to increase just enough to maintain the beam intensity for the duration of the sweep. The amplitude of this negative pulse can be adjusted by means of the NEG. GATE ADJ. potentiometer.

3-9 CALIBRATOR

The calibrator circuit is a plate-coupled multivibrator which free runs at approximately 1000 cps. The 100-volt squarewave output is positive going with the base line clamped at ground by crystal diode CR2. The output voltage is selected by the attenuator in the CALIBRATOR selector switch. The output half of the multivibrator tube, V32, is a pentode whose screen serves as the plate for the multivibrator, while the pentode plate serves to electron-couple the multivibrator to the output circuit.

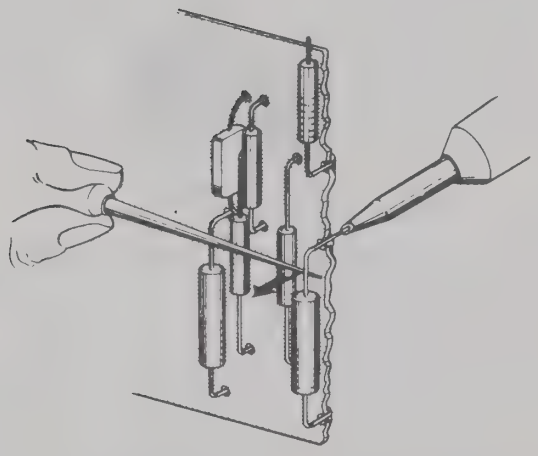
SERVICING ETCHED CIRCUIT BOARDS

Excessive heat or pressure can lift the copper strip from the board. Avoid damage by using a low power soldering iron (50 watts maximum) and following these instructions. Copper that lifts off the board should be cemented in place with a quick drying acetate base cement having good electrical insulating properties.

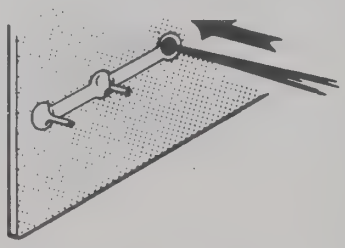
Use only high quality rosin core solder when repairing etched circuit boards. NEVER USE PASTE FLUX. After soldering, clean off any excess flux and coat the repaired area with a high quality electrical varnish or lacquer.

A break in the copper should be repaired by soldering a short length of tinned copper wire across the break.

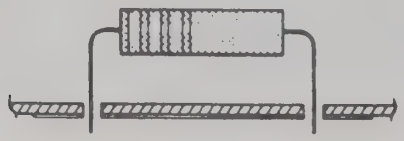
When replacing tube sockets it will be necessary to lift each pin slightly, working around the socket several times until it is free.



1. Apply heat sparingly to lead of part to be replaced. Remove part from card as iron heats the lead.



2. Using a small awl, carefully clean inside of hole left by old part.



3. Bend clean tinned leads on new part and carefully insert through holes on board.

4. Hold part against board and solder leads. Avoid overheating the board.

SECTION IV
MAINTENANCE

4-1 GENERAL INFORMATION

This section contains instructions for testing, adjusting and trouble-shooting in the Model 150A Oscilloscope. If the instrument is operating, the Condensed Test and Adjustment Procedure, paragraph 4-3, is a fast method of checking the basic adjustments and operation of the instrument. The Trouble-Shooting Procedure, paragraph 4-4, is a rapid means of isolating a section of the instrument that is not functioning. The Detailed Test and Adjustment Procedure is an expansion of the condensed test and adjustment procedure.

Paragraph 4-2 deals with the physical layout of the instrument and routine maintenance procedures.

Schematic Diagrams and the Table of Replaceable Parts are located at the end of this section.

The following test equipment is used for testing and adjusting the Model 150A Oscilloscope during manufacture. Equivalent test equipment may be used.

1) A test oscilloscope such as the hp Model 150A equipped with an hp Model 152 Dual Trace Amplifier.

2) A high impedance dc vacuum tube voltmeter calibrated to an accuracy of ±1%, such as an hp Model 410B with an hp Model 459A DC Voltage Multiplier.

3) A high impedance ac vacuum tube voltmeter, such as an hp Model 400D/H/L.

4) A variable power line transformer with a minimum rating of 7.5 amps, equipped with a voltmeter, accurate within 1 volt.

5) A square wave generator such as an hp Model 211A.

6) A sine wave oscillator with a maximum frequency of at least 50,000 cycles, such as an hp Model 200CD.

7) An accurate time mark generator suitable for sweep speed calibration.

8) A voltmeter calibration generator such as an hp Specification 23678.

9) A frequency response generator such as an hp Specification 23679.

4-2 ROUTINE SERVICING

Routine servicing covers air filter cleaning, cabinet removal, adjustments required when tubes are changed, CRT replacement, and 230-volt operation.

Each of the major sections of the instrument is located in a particular area. Figure 4-1 indicates the location of these sections. The Horizontal Amplifier and the Sweep Generator and Sync Amplifier sections will swing out when the instrument is out of the cabinet. These sections are held in place by fasteners near the panel.

A. CLEANING THE AIR FILTER

Inspect the air filter often when the Oscilloscope is in constant use.

The air-filter element in the 150A is a renewable type. It is located in the bottom of the instrument cabinet and is removed by pulling straight down. In the rack mount pull the filters to the rear. To re-new the filter element, wash in warm water and detergent, then recoat with an adhesive made for this purpose. Filter Coat No. 3 made by Research Products Corp., Madison 10, Wisconsin is suitable. If you have difficulty obtaining it, see your Hewlett-Packard Field Sales Engineer.

Apply Filter Coat No. 3 with the HANDIKOTER spray applicator directed at the intake side of the filter until visible baffles are liberally coated. Do not spray to the extent that adhesive runs or drips off the surface of the filter. Filter is now ready for service.

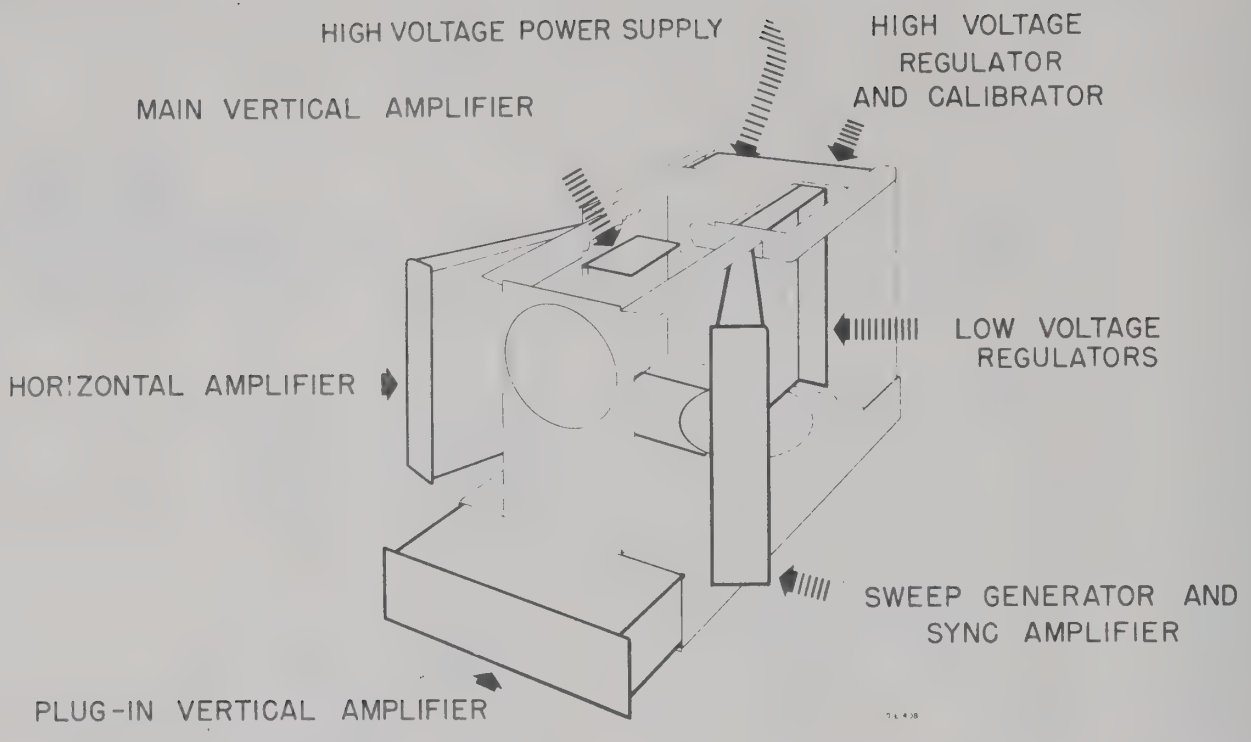


Figure 4-1. Sections of the Model 150A Oscilloscope

B. REMOVING THE CABINET

CAUTION

When the cabinet is removed, dangerous voltages are exposed. Observe adequate safety precautions.

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1) Cabinet Model -
Remove chassis from the cabinet by removing four screws on the rear of the cabinet and sliding the chassis forward.

2) Rack Model -
To slide the rack mount model forward, remove the two large screws at the rear of the dust cover, turn the two handles at the bottom of the panel, and slide out.

To tilt up, remove the small flat head screws locking the instrument in a horizontal position. They are accessable on either side of interior of the plug-in amplifier compartment.

To remove the instrument from the dust cover, remove the bracket that holds the power cord on the back of the dust cover, slide the instrument all the way forward and release the catches on each slide. Reverse this procedure when replacing the instrument.

If the power cord catches and the instrument will not slide completely into the cabinet, remove the power cord bracket on the rear of the dust cover and free the cord.

C. REPLACING AND ADJUSTING THE CRT

WARNING

HANDLE THE CATHODE RAY TUBE CAREFULLY, IT IS FRAGILE. When handling the tube wear a protective face shield, gloves, and leather apron or other suitable safety clothing.

After installing a new CRT, turn the INTENSITY control to minimum before applying power. This is to prevent burning the phosphor.

Replacing the CRT -

1) Disconnect the leads on the neck of the tube.

2) Remove the bezel.

3) Slide the tube forward through the panel.

4) Insert the new tube in the socket and replace

the bezel. It may be necessary to loosen the socket clamp and slide the tube back before replacing the bezel.

5) Replace the leads on the neck of the tube.

Adjusting the CRT -

1) Set the INTENSITY control to full CCW position. Turn the instrument on and allow to warm up.

2) Set SWEEP MODE control to FREE RUN.

3) Adjust the INTENSITY control to obtain a weak trace; adjust the FOCUS control for a sharp trace, and with the vertical position control, center the trace vertically.

4) Align trace with the graticule (see Figure 2-8).

5) Making certain that the CRT face is close to, but not touching the bezel, tighten the clamp on the CRT socket.

6) Adjust astigmatism and FOCUS controls for optimum focus and spot definition. The astigmatism control is located inside and below the front edge of the cabinet mount top access hatch.

7) Check the vertical and horizontal voltage calibration.

D. 230 VOLT OPERATION

The Oscilloscope is normally shipped from the factory with the dual primary windings of the power transformers connected in parallel for use on 115-volt power lines, unless otherwise specified. To connect the primary windings of T2 and T3 for use on 230 volt power, refer to the schematic diagram of the Low Voltage Power Supply. Install the thermistors and power line fuse specified for 230 volt operation in the Table of Replaceable Parts.

TABLE 4-1. TUBE REPLACEMENT CHART

Circuit Reference	Type	Function	Adjustment Required
		MAIN VERTICAL AMPLIFIER	
V1, 2	6CL6	Input Amplifier	Adjust the Main Vertical Amplifier Gain, R5
V3, 4	6DJ8	Cathode Follower	None
V5, 6	6197	Output Amplifier	Adjust the Main Vertical Amplifier Gain, R5
V7	6AU8	Internal-Sync Preamplifier	None
		SWEEP GENERATOR	
V8	6DJ8	Sync Amplifier Inverter	None
V9	6DJ8	Sync Schmitt Trigger	Adjust Sync Circuits R66, R72
V10	6DJ8	Sawtooth Start-Stop Trigger	Adjust Start-Stop Trigger upper limit, R88 and Sweep Preset, R103
V11	6DJ8	Cathode Follower	None
V12	6DJ8	Cathode Follower	
V13	6AL5	Integrator Switch	
V14	6485	Feedback Integrator	
V15	6DJ8	Cathode Follower	
V16	6DJ8	Sawtooth Inverter and Retriggering Holdoff Cathode Follower	Adjust Sweep Amplitude, R135
V17	6DJ8	Retriggering Bias Control Tube	None

TABLE 4-1. TUBE REPLACEMENT CHART (CONT'D.)

Circuit Reference	Type	Function	Adjustment Required
		HORIZONTAL AMPLIFIER	
V18	6AN8	Ext. Horizontal Input Preamplifier	Adjust Preamplifier Gain, R178 and Preamplifier Balance, R185
V19	6DJ8	Amplifier-Phase Inverter	Adjust Horizontal Gain R199 and Horizontal Balance, R189, R207
V20, 21	6485	Push-Pull Amplifier	
V22	6DJ8	Cathode Followers	None
V23, 24	6CL6	Output Amplifier	Adjust Horizontal Gain, R199 and Horizontal Balance, R189, R207
V25	6DJ8	Output Cathode Follower	None
V26	6DJ8	Capacitance Driver	
		HIGH VOLTAGE SUPPLY AND CRT CIRCUIT	
V27	6AU5GT	60 kc, High Voltage Oscillator	None
V28	6DJ8	High Voltage Control Tube	Adjust HighVoltage, R275, R267
V29	1X2B	Beam High Voltage Rectifier	None
V30	1X2B	Intensity High Voltage Rectifier	
V31	5AMP	Cathode Ray Tube	Adjust Astigmatism, R283 Adjust Vertical Gain, R5; Horizontal Gain, R199 and Horizontal Balance, R189, R207
		CALIBRATOR	
V32	6U8	1 kc Multivibrator	None
		LOW VOLTAGE POWER SUPPLY	
V33, 34, 35	12B4A	+400 Volt Regulator	None
V36	6BH6	+400 Volt Control	
V37, 38, 39	12B4A	+260 Volt Regulator	
V40	6BH6	+260 Volt Control	
V41, 42	12B4A	+130 Volt Regulator	
V43	6BH6	+130 Volt Control	
V44, 45, 46	12B4A	-150 Volt Regulator	
V47	6BH6	-150 Volt Control	Check -150 Volt Output
V48	5651	Power Supply Reference	
V49	12AX7	-78 Volt Control	Check -78 Volt Output
V50	12B4A	-78 Volt Regulator	None

4-3 CONDENSED TEST AND ADJUSTMENT PROCEDURE

All the basic tests and adjustments are covered in the following Table 4-2. This procedure is for instruments that are functioning. If the instrument is not operating, refer to paragraph 4-4, Trouble-Shooting Procedure.

TABLE 4-2
CONDENSED TEST AND ADJUSTMENT PROCEDURE

4-4 TROUBLE-SHOOTING PROCEDURE

The Model 150A Oscilloscope is composed of several basic sections or circuits. Repair and test time can be minimized by following a procedure that will isolate the section needing repair. It is important to isolate the problem before changing any internal adjustments. In the majority of cases, only a tube change will be required.

A. CHECK AC POWER CIRCUIT

All ac power circuits are normal if the fan will operate with the instrument turned on and connected to a suitable power source.

If the fan will not operate:

1) Check the power line fuse mounted near the base of the CRT. Access in cabinet models is through the top hatch and in rack models by sliding the instrument out of the rack.

The cause of a blown line fuse can usually be found in the low voltage regulator input circuits. Check silicon rectifiers, filter capacitors, etc.

2) Check the thermal overload on the top of the instrument at the rear of the hinged sweep generator chassis. Access to the thermal overload is same as for the line fuse. To reset, push the small button.

The thermal overload will trip when the cabinet temperature exceeds approximately 150°F. A dirty or obstructed air filter or a high ambient temperature are the usual causes of excessive cabinet temperature.

B. CHECK DC LOW VOLTAGE CIRCUITS

Check dc voltages at marked test points on the CALIBRATOR AND HIGH VOLTAGE board at the top rear of the instrument.

If all voltages are correct, check the fuses for the plug-in amplifier. These fuses are located at the rear of the opening for the plug-in amplifier.

If the voltages are incorrect, turn off power for a full minute and turn on again. If the instrument fails to come on the overload relay may have tripped, check for a resistance of about 30 ohms between the -78 volt test point and ground with a plug-in amplifier installed and the line cord disconnected. A resistance of 1,000 ohms or more indicates an open heater. A heater-cathode short in any tube may operate the overload relay.

If you replace any tubes refer to Table 4-1, Tube Replacement Chart, and Table 4-2, Condensed Test and Adjustment Procedure.

C. CHECK HIGH VOLTAGE CIRCUITS

If a spot or trace is visible on the face of the tube, the high voltage circuits are operating.

If a spot or trace is not present, short circuit the horizontal deflection plates of the CRT with an insulated clip lead. With a second clip lead short circuit the vertical deflection plates. This should produce a spot near the center of the CRT at some setting of the INTENSITY control. If not, check the high voltages on the High Voltage and Calibrator board at the test points marked CRT CATHODE and CRT GRID. The cathode should measure -4800 volts. With the INTENSITY control at minimum the grid should measure approximately -5000 volts.

Resistors R261, 266, or 276 located on the High Voltage and Calibrator board, may cause incorrect high voltage. Check V28 if R261 is defective.

If you replace any tubes or components, refer to Table 4-1, Tube Replacement Chart and Table 4-2, Condensed Test and Adjustment Procedure.

D. CHECK HORIZONTAL AND VERTICAL AMPLIFIERS

The Horizontal and Vertical Amplifiers are functioning properly when a spot on the face of the CRT can be easily and smoothly positioned by the horizontal and vertical position controls.

If a spot is not visible on the screen:

1) Short the horizontal deflection plates together, if this produces a spot that can be positioned and deflected by a vertical input, the vertical amplifier is functioning properly.

2) Short the vertical deflection plates together, if this produces a spot that can be positioned and deflected by a horizontal input, the horizontal amplifier is functioning properly.

The amplifiers in the instrument are direct coupled and balanced, and corresponding voltages in each side of the circuit must remain balanced to keep the spot on the screen. The settings of gain, balance and positioning controls can introduce unbalanced voltages and should be considered when checking an amplifier.

To check an inoperative amplifier, short circuit corresponding points in each stage until a point is reached where the spot does not return to the screen. For example, in the Horizontal Amplifier, if the spot is on the screen when the deflection plates are connected together, remove the jumper from between the deflection plates and connect it between the plate (pin 6) of V23 and the plate (pin 6 of V24). Work

TABLE 4-2. CONDENSED TEST AND ADJUSTMENT PROCEDURE

TEST	EXTERNAL EQUIPMENT REQUIRED	PROCEDURE	ADJUST	NOTES
1. Low Voltage Power Supply	Dc vtvm with 1% accuracy	Measure all low voltage power supply outputs, should be within the following limits -- -150 ±4 volts - 78 ±2 volts +130 ±4 volts +260 ±8 volts +400 ±12 volts	Do not adjust if within limits. Adjust R379 for -150 and R382 for -78, repeat as necessary.	Check CALIBRATOR and SWEEP TIME calibration if -150 volt is adjusted.
2. Horizontal Amplifier Gain	None	Connect 10 volts from CALIBRATOR to EXT. HORIZ. INPUT. HORIZ. SENSITIVITY to unmarked vertical position.	Set R199 for 5.6 cm between spots. Set C82 to eliminate "tails" on spots.	(*)
3. Horizontal Amplifier Balance	None	No INPUT, no sweep, HORIZ. SENS. X100, position spot on screen. Switch to X5 and note spot location. Return to X100 and move spot to position noted in X5 with HORIZ. POSITION.	Center spot with R207. Switch to X1 and center spot with R189.	Check HORIZ. GAIN if adjustments are made. (*)
4. Plug-In Vertical Amplifier		See plug-in amplifier manual for balance and calibration adjustments.		
5. Main Vertical Amplifier Gain	400 cycle sine wave source, plug-in amplifier with accurately adjusted 20 db gain in .05 VOLTS/CM position.	Connect .2 VOLTS from CALIBRATOR to INPUT with VERT. SENS. on .05 VOLTS/CM and VERNIER in CAL.	Adjust R5 for exactly 4 cm vertical deflection.	(*)
6. Sync Circuits	Insulated dc voltmeter, 50 kc sine wave source, ac coupled test oscilloscope with 10:1 probe.	Connect dc voltmeter between pins 1 and 6 of V8 and with no external INPUT	Adjust TRIGGER LEVEL for zero volts on meter.	(*)
		Connect 50 kc sine wave with 2 volt peak-to-peak amplitude to EXT. SYNC. INPUT. Calibrate test oscilloscope for 1 volt/cm and connect to junction of R65 and S2.	Adjust R66 and R72 for pips spaced exactly 1/2 volt above and 1/2 volt below center of waveform.	If parasitic oscillations present rotate R66 max. CCW. If no pips visible rotate R66 CW just short of oscillation then adjust R72 for pips. (*)
7. Sweep Amplitude and Start-Stop Trigger	Dc vtvm test oscilloscope with 10:1 probe.	With no INPUT set SWEEP TIME to 2 SEC/CM, EXT AC SYNC, SWEEP MODE in FREE RUN. Connect vtvm between ground and pin 2 of V10.	Adjust R88 for -15 volt at end of sweep.	If unable to set adjust R135 until able to set R88. (*)
		Move vtvm to pin 8 of V15.	Adjust R135 for -110 to -115V at end of sweep.	(*)
		Change SWEEP TIME to .1 MICROSECONDS/CM with VERNIER on CAL. and HORIZ. SENS. on X1. Remove vtvm and connect test oscilloscope probe to pin 8 of V15.	Adjust C40 for maximum amplitude with no distortion on negative tip.	
8. Sweep Preset	DC vtvm	With no INPUT set SWEEP TIME to .1 MILLISECONDS, SWEEP MODE in PRESET, and SYNC. selector to INT. Connect dc vtvm between ground and pin 2 of V10.	Slowly adjust R103 until sweep begins. Repeat several times and note voltage. Set R103 for 1.5 volts more positive than voltage level just before sweep starts.	(*)

(*) If you change a tube, see the Tube Replacement Chart, Table 4-1.

4-4 TROUBLE-SHOOTING PROCEDURE

The Model 150A Oscilloscope is composed of several basic sections or circuits. Repair and test time can be minimized by following a procedure that will isolate the section needing repair. It is important to isolate the problem before changing any internal adjustments. In the majority of cases, only a tube change will be required.

A. CHECK AC POWER CIRCUIT

All ac power circuits are normal if the fan will operate with the instrument turned on and connected to a suitable power source.

If the fan will not operate:

1) Check the power line fuse mounted near the base of the CRT. Access in cabinet models is through the top hatch and in rack models by sliding the instrument out of the rack.

The cause of a blown line fuse can usually be found in the low voltage regulator input circuits. Check silicon rectifiers, filter capacitors, etc.

2) Check the thermal overload on the top of the instrument at the rear of the hinged sweep generator chassis. Access to the thermal overload is same as for the line fuse. To reset, push the small button.

The thermal overload will trip when the cabinet temperature exceeds approximately 150° F. A dirty or obstructed air filter or a high ambient temperature are the usual causes of excessive cabinet temperature.

B. CHECK DC LOW VOLTAGE CIRCUITS

Check dc voltages at marked test points on the CALIBRATOR AND HIGH VOLTAGE board at the top rear of the instrument.

If all voltages are correct, check the fuses for the plug-in amplifier. These fuses are located at the rear of the opening for the plug-in amplifier.

If the voltages are incorrect, turn off power for a full minute and turn on again. If the instrument fails to come on the overload relay may have tripped, check for a resistance of about 30 ohms between the -78 volt test point and ground with a plug-in amplifier installed and the line cord disconnected. A resistance of 1,000 ohms or more indicates an open heater. A heater-cathode short in any tube may operate the overload relay.

If you replace any tubes refer to Table 4-1, Tube Replacement Chart, and Table 4-2, Condensed Test and Adjustment Procedure.

C. CHECK HIGH VOLTAGE CIRCUITS

If a spot or trace is visible on the face of the tube, the high voltage circuits are operating.

If a spot or trace is not present, short circuit the horizontal deflection plates of the CRT with an insulated clip lead. With a second clip lead short circuit the vertical deflection plates. This should produce a spot near the center of the CRT at some setting of the INTENSITY control. If not, check the high voltages on the High Voltage and Calibrator board at the test points marked CRT CATHODE and CRT GRID. The cathode should measure -4800 volts. With the INTENSITY control at minimum the grid should measure approximately -5000 volts.

Resistors R261, 266, or 276 located on the High Voltage and Calibrator board, may cause incorrect high voltage. Check V28 if R261 is defective.

If you replace any tubes or components, refer to Table 4-1, Tube Replacement Chart and Table 4-2, Condensed Test and Adjustment Procedure.

D. CHECK HORIZONTAL AND VERTICAL AMPLIFIERS

The Horizontal and Vertical Amplifiers are functioning properly when a spot on the face of the CRT can be easily and smoothly positioned by the horizontal and vertical position controls.

If a spot is not visible on the screen:

1) Short the horizontal deflection plates together, if this produces a spot that can be positioned and deflected by a vertical input, the vertical amplifier is functioning properly.

2) Short the vertical deflection plates together, if this produces a spot that can be positioned and deflected by a horizontal input, the horizontal amplifier is functioning properly.

The amplifiers in the instrument are direct coupled and balanced, and corresponding voltages in each side of the circuit must remain balanced to keep the spot on the screen. The settings of gain, balance and positioning controls can introduce unbalanced voltages and should be considered when checking an amplifier.

To check an inoperative amplifier, short circuit corresponding points in each stage until a point is reached where the spot does not return to the screen. For example, in the Horizontal Amplifier, if the spot is on the screen when the deflection plates are connected together, remove the jumper from between the deflection plates and connect it between the plate (pin 6) of V23 and the plate (pin 6 of V24). Work

toward the input, shorting plate-to-plate, until a point is reached where the spot does not appear. This locates the unbalanced portion of the circuit.

E. CHECK SWEEP GENERATOR

1) Set the HORIZ. SENSITIVITY selector to "X1" and the SWEEP MODE control maximum clockwise to "FREE RUN". In cabinet models, set the SINGLE SWEEP-NORMAL switch at "NORMAL"; or in rack models set the SWEEP reset switch to "INT".

2) A repetitive sweep should be obtained in each position of the SWEEP TIME/CM selector. If the generator is inoperative, try the following steps in the order listed.

NOTE

Turn the Model 150A Oscilloscope power off before removing or installing the tubes discussed in this procedure. All voltages are measured between ground and the indicated point with an hp Model 410B High Impedance Vacuum Tube Voltmeter.

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3) Check tubes V10 through V17, one at a time by substitution. Always replace the original tube if proper operation is not restored.

4) Check the adjustment of R135, SWEEP AMPLITUDE ADJ., by rotating through the entire range of adjustment.

a. If the generator operates at some setting, complete adjustment Number 7, described in Table 4-2.

b. If adjustment does not restore operation, set R135 near the mechanical center of the adjustment range.

5) Check the adjustment of R88, UPPER HYSTERESIS LIMIT ADJ., by rotating through the entire range of adjustment.

a. If the generator operates at some setting, complete adjustment Number 7, described in Table 4-2.

b. If adjustment does not restore operation, set R88 near the mechanical center of the adjustment range.

6) When the sweep generator will not "free run" the dc feedback loop can be opened and the generator forced into two specific conditions. Any analysis of voltage measurements, in these two conditions, will help in isolating the problem. The change in voltage between the two conditions is far more significant than the absolute voltages.

Table 4-3 contains the procedure for forcing the sweep generator as well as a tabulation of all the significant voltages.

4-5 DETAILED TEST AND ADJUSTMENT PROCEDURES

The complete test and adjustment procedures for the oscilloscope follow. In general, only one or two of the procedures will be needed and they can be done without completing all other tests.

A ten to fifteen minute warm-up and a check of the power supply output voltages is always recommended before making any other tests or adjustments.

The specifications for your instrument are given in the front of this manual. The following test procedure contains extra checks to help you analyze a particular instrument. These extra checks and the data they contain can not be considered as specifications.

This detailed procedure is outlined in the Condensed Test and Adjustment Procedure, Table 4-2.

4-6 LOW VOLTAGE POWER SUPPLY

The low voltage power supply regulator circuits are located on an etched circuit board on the right side at the rear of the instrument. Figure 4-2 locates the adjustments on this board.

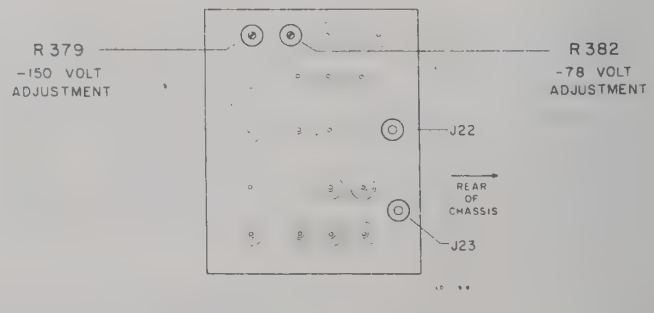

Figure 4-2. Low Voltage Power Supply Adjustments

TABLE 4-3. SWEEP GENERATOR FORCED VOLTAGES

Set oscilloscope controls as follows:

SWEEP TIME/CM - - - - - - - - - - - - - - - - - - 10 MILLISECONDS
SWEEP MODE - - - - - - - - - - - - - FREE RUN (maximum clockwise)
HORIZ. SENSITIVITY - - - - - - - - - - - - - - - - INT. SWEEP "X1"
SINGLE SWEEP-NORMAL (cabinet) - - - - - - - - - - - - - NORMAL
or
SWEEP RESET (rack) - INT

REMOVE V17 and compare measured voltages with those listed below.

The "SWEEP RESET" condition is obtained by connecting V10 pin 2 to ground.

The "SWEEP COMPLETED" condition is obtained by disconnecting V10 pin 2 from ground.

MEASURE THE VOLTAGE AT	SWEEP RESET	SWEEP COMPLETED	AVERAGE Δ E
V11 pin 3	+ 47 ± 5	+132 ± 5	+ 85
8	+ 53 ± 5	+135 ± 5	+ 82
V12 pin 2	- 25 ± 5	+0.4 ±0.2	+ 25
V13 pin 5	- 2 ± 1	+ 3 ± 1	+ 5
V14 pin 1	-2.5 ±0.5	-0.5 ± 1	+ 2
5	+165 ±10	+ 30 ±10	-135
V15 pin 8	- 2 ± 1	-125 ± 5	-123
V16 pin 1	+ 87 ± 5	+160 ±10	+ 73
7	- 80 ± 5	- 7 ±10	+ 73

REPLACE V17, REMOVE V11 and compare measured voltages with those listed below.

The "SWEEP RESET" condition is obtained automatically.

The "SWEEP COMPLETED" condition is obtained by connecting V14 pin 1 to ground.

MEASURE THE VOLTAGE AT	SWEEP RESET	SWEEP COMPLETED	AVERAGE Δ E
V17 pin 2	- 70 ± 5	0 ± 3	+ 70
8	- 43 ± 5	- 3 ± 3	+ 40
V10 pin 2	Same as V17 pin 8		

The following adjustment procedure applies to low voltage power supply regulators marked with hp Stock No. 150A-65H.

A. ADJUST LOW VOLTAGE POWER SUPPLY

CAUTION

After repair work in any power supply circuit, turn the intensity control full counterclockwise before applying power. Failure to do this may result in a damaged cathode ray tube.

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1) Remove the 150A from the cabinet; turn on, and allow to warm up for 5 minutes.

2) Set the SWEEP MODE control just off of the PRESET position.

3) All regulated voltages can be conveniently measured through the access hole over the High-Voltage Power Supply etched-circuit board at the top-rear of the instrument chassis.

4) Adjust R379 to obtain -150 volts.

5) Adjust R382 to obtain -78 volts.

6) Repeat steps 4 and 5 as required.

7) Measure the -130, -260, and -400 volt outputs. The voltages of these supplies are fixed by 1% resistors and should be within 3% of their specified voltages.

8) Adjust R1323 to obtain 31.5 volts between the junction of R1323 and R1324 (-) and the negative terminal of CR5 (-). This control is located at the rear of the instrument on the left side and adjusts the unregulated dc heater supply for the Horizontal and Main Vertical Amplifiers. An isolated dc voltmeter must be used.

B. TEST LOW VOLTAGE POWER SUPPLY REGULATION AND RIPPLE

1) You may wish to check the regulation of each power supply voltage as the power line voltage is varied between 102 and 128 volts. All regulated voltages should remain within ±1% over this range of line voltage.

2) Measure the ripple voltage on the various supplies, they should approximate the values indicated in Table 4-4 with the power line voltage set at 115 (230) volts. Adjust the value of R373 to lower the ripple on the -150 volts supply, and the value of R326 to lower the ripple on the -400 volt supply.

TABLE 4-4. REGULATED POWER SUPPLY TOLERANCES

Nominal Voltage	Normal Ripple at 115 volts	Output Voltage Range
- 78	- - -	- 78
-150	1.0 mv	-150
130	1.0 mv	-126 to +134
260	1.5 mv	-252 to +268
-400	2.0 mv	-388 to +412

3) Ripple voltage measured at the input to each low voltage regulator should normally not exceed 5 volts rms.

4-7 HIGH VOLTAGE POWER SUPPLY AND CALIBRATOR

The high voltage regulator and calibrator circuits are located on an etched circuit board along the top of the instrument at the back. The high voltage oscillator and rectifiers are located in a metal box below this etched circuit board. The following adjustment procedures apply to high voltage regulator and calibrator boards marked with hp Stock No. 150A-65K and high voltage and rectifier assembly hp Stock No. 150A-11C.

A. ADJUST HIGH VOLTAGE POWER SUPPLY

The voltage to be measured is approximately -5000 volts. Use a high resistance probe such as an hp Model 459A DC Voltage Multiplier with the Model 410B Voltmeter.

1) Adjust R275 to set the CRT cathode voltage to -4800 volts. Measure this voltage at the point marked "CRT CATHODE" on the Calibrator and High Voltage Regulator board.

2) Set the INTENSITY control to "10 o'clock" and the SWEEP MODE control in FREE RUN.

3) With no input to the oscilloscope, swing out the Sweep Generator Assembly and adjust R267 until the trace is just visible. R267 is located behind the front panel near the INTENSITY control.

4) Check CRT cathode voltage regulation as line voltage is varied from 102 to 128 volts. The variation should be within ±1%.

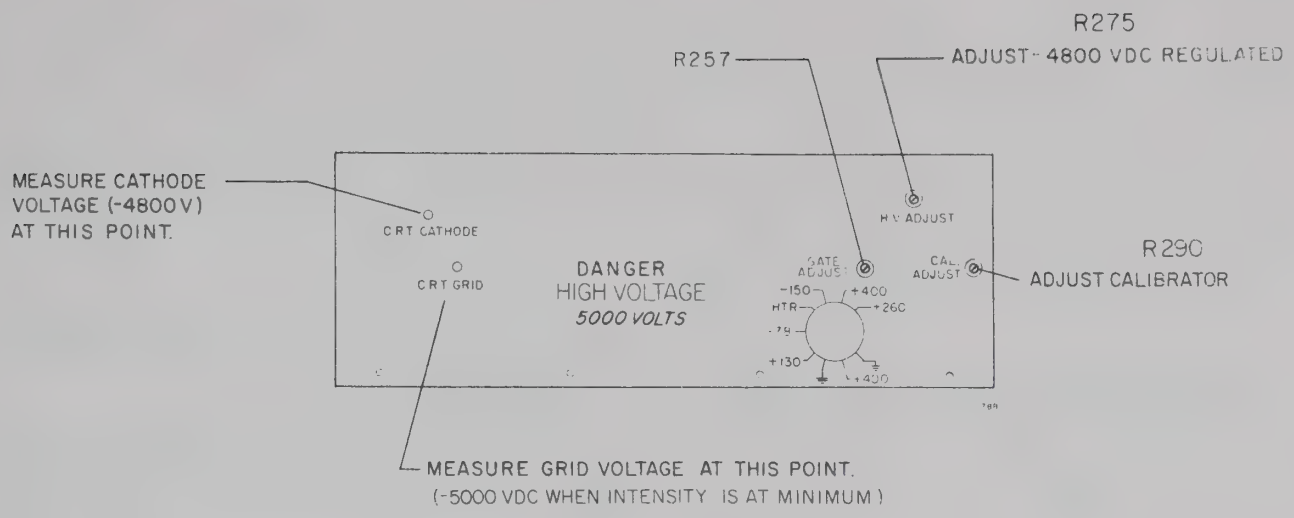

Figure 4-3. High Voltage Regulator and Calibrator Adjustments

B. ADJUST UNBLANKING GATE

1) Set the SWEEP TIME/CM to 50 MILLISECONDS and SWEEP MODE to FREE RUN.

2) Turn up INTENSITY control until the trace is visible. The trace should have equal brightness throughout the sweep.

3) Observe the 10, 20, 50, and 100 MILLISECONDS/CM sweep ranges and adjust R257 for uniform trace brilliance on all ranges. The GATE ADJUST control, R257, is located inside the High Voltage Rectifier Assembly and is adjusted through a hole in the Calibrator and High Voltage Supply board.

C. ADJUST THE CALIBRATOR OUTPUT

1) Set the CALIBRATOR switch to the "6.3 V AC" position and check the voltage at the calibrator output terminal, it should be approximately 6.3 volts rms.

2) Remove tube V32. Connect a dc vacuum tube voltmeter with a high input resistance to the CALIBRATOR output terminal.

3) Set CALIBRATOR to 100 volts output. Adjust R290 to set the dc voltage at the CALIBRATOR output terminal to +100 volts. If R290 adjustment range is not wide enough to permit setting this voltage, try replacing CR1 and/or CR2 diodes. Diode CR1 is located on the underside of the high voltage power supply and calibrator board at the top rear of the instrument. Diode CR2 is located on the CALIBRATOR switch.

4) The remaining voltages, measured with a dc voltmeter, should fall within ±3% of the indicated CALIBRATOR output. Checking the accuracy of the 50 through .1 volt ranges will verify all ranges since all the voltage divider circuits are checked on these ranges.

5) Replace V32.

D. TEST THE CALIBRATOR GROUND CLAMP

1) Check the CALIBRATOR square wave symmetry, it should be better than 40-60%. Replacing V32 will usually restore symmetry.

2) Set CALIBRATOR to "1 VOLT" and connect the CALIBRATOR output to the test oscilloscope vertical input.

3) Set the test oscilloscope for positive-up dc and a vertical deflection sensitivity of 1 volt per centimeter. Position the bottom of the square wave CALIBRATOR signal across the center of the test oscilloscope screen.

4) Rotate the CALIBRATOR to "20 VOLTS". If the bottom of the square wave shifts vertically more than 1 centimeter, diode CR2 is defective and must be replaced. A certain amount of shift can be expected due to overload of the test oscilloscope vertical amplifier.

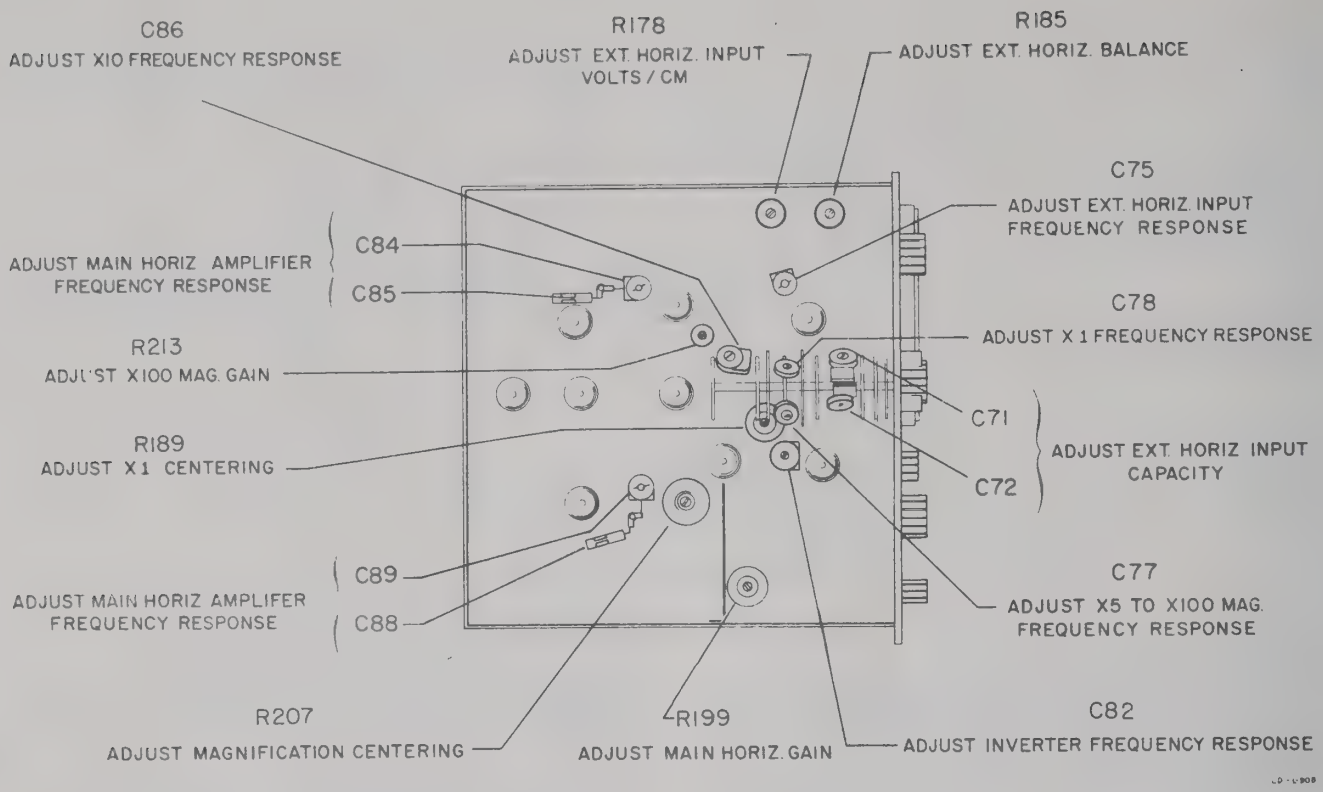

Figure 4-4. Horizontal Amplifier Adjustments

4-8 HORIZONTAL AMPLIFIER

The horizontal amplifier is located on the left side of the instrument on a swing out chassis. The chassis is locked in place by a captive fastener near the center of the board next to the panel. The following procedure applies to Horizontal Amplifiers marked with ℗ Stock No. 150A-65F. Figure 4-4 locates the various adjustments on the Horizontal Amplifier.

A. ADJUST HORIZONTAL AMPLIFIER GAIN

1) Set the HORIZ. SENSITIVITY control to the unmarked vertical test position.

2) Set the CALIBRATOR to 10 VOLTS and connect to the EXT. HORIZ. INPUT.

3) Slowly adjust R199 to give a horizontal deflection of 5.6 centimeters. It will be necessary to adjust the HORIZ. POSITION control to keep the spots centered.

4) Adjust C82 to eliminate any overshoot or undershoot on the spots. With C82 properly adjusted the spots will be well defined with no "tails".

5) Disconnect all cable.

B. ADJUST HORIZONTAL AMPLIFIER BALANCE

1) Set the HORIZ. SENSITIVITY control to X100 and adjust the HORIZ. POSITION to bring the spot to the approximate center of the CRT. Keep the INTENSITY low to avoid burning the phosphor.

2) Switch to the X5 range and note the location of the spot. Switch back to X100 and return the spot to the location noted when on the X5 range using the HORIZ. POSITION control.

3) Center the spot with R207.

4) Switch from X5 to X1 and note the spot shift. Adjust R189 for minimum spot shift when switching between X1 and X5.

5) Repeat paragraphs 4-8A and 4-8B until both balance and gain are correct.

C. TEST HORIZONTAL AMPLIFIER FOR HUM

1) Set the HORIZONTAL SENSITIVITY switch to X1, stop the sweep with the SWEEP MODE control and center the spot. Keep the INTENSITY low to prevent burning the screen.

CAUTION

The ac vacuum tube voltmeter used for this check should be isolated from ground. Both input terminals will be 200 volts above ground.

---

2) Connect an ac VTVM between the CRT horizontal deflection plates. This connection may be made between V25 and V26 on the horizontal amplifier. One plate is the junction of R244 and C95, and the other is the junction of R245 and C96.

3) The ripple voltage measured should not exceed 0.07 volts rms. If not, try replacing V23 or V24.

4) Set the HORIZONTAL SENSITIVITY switch to X100 and center the spot.

5) The ripple voltage measured should not exceed 0.25 volts rms. If the voltage is high, check the ripple in the low voltage power supplies.

D. TEST HORIZONTAL AMPLIFIER FOR LINEARITY

1) Connect an ac VTVM between the CRT horizontal deflection plates.

2) Connect a 1000 cycle sine wave to the EXT. HORIZ. INPUT and set the HORIZ. SENSITIVITY switch to the unmarked vertical test position.

3) Adjust the amplitude of the 1000 cycle voltage to produce exactly 1.0 volt on the ac voltmeter with the trace centered on the screen.

4) Adjust the HORIZ. POSITION control to position the trace at the extreme right and left edges of the ruled portion of the graticule. The voltmeter indication should not drop below 0.95 volt. Try replacing V23, V24, V25, and/or V26 to improve linearity.

E. ADJUST HORIZONTAL PREAMPLIFIER BALANCE

1) With no sweep and no horizontal or vertical input, obtain a spot of low intensity. Set HORIZ. SENSITIVITY to ".2 VOLTS/CM" and position spot near center of screen with HORIZ. POSITION control.

2) Rotate the horizontal VERNIER control from stop-to-stop.

3) Adjust R185 until spot does not move when VERNIER control is rotated.

F. ADJUST HORIZONTAL PREAMPLIFIER GAIN

1) Set the Horizontal VERNIER to "CAL".

2) Connect CALIBRATOR output terminal to "EXT. HORIZ. INPUT" and switch HORIZ. SENSITIVITY to "1 VOLTS/CM".

3) Set CALIBRATOR switch to 10 VOLTS and adjust R178 to give a horizontal deflection of 10 centimeters.

4) Set HORIZ. SENSITIVITY to ".2 VOLTS/CM" and CALIBRATOR switch to "2.0 VOLTS". Adjust R213 to give a horizontal deflection of 10 centimeters.

5) Check 10 centimeter deflection for other HORIZ. SENSITIVITY switch settings under EXT. INPUT. Use appropriate CALIBRATOR output. Calibration should be within 3%. If not, measure and replace R193, R214, R215, R216, and/or R217. These resistors must all be within ±1% of their marked values.

6) Repeat the procedures in paragraphs 4-8E and 4-8F until no additional adjustment is necessary.

7) Disconnect all test instruments and cables.

G. ADJUST HORIZONTAL SQUARE-WAVE RESPONSE

1) Connect the 75 ohm output of an hp Model 211A Square Wave Generator to the EXT. HORIZ. INPUT. Connect the 600 ohm output of the Generator to the EXT. SYNC. INPUT of the oscilloscope.

2) Set the SYNC switch to EXT. AC and the SWEEP MODE control maximum counterclockwise but not on PRESET.

3) Set the HORIZ. SENSITIVITY control to the unmarked vertical test position.

4) Connect the SWEEP OUTPUT to the VERTICAL INPUT.

5) Set the vertical VOLTS/CM switch to 1, VERNIER to CAL. and POLARITY switch to AC POS. UP.

6) Set the Square Wave Generator to 10 kc.

7) Using a dual channel test oscilloscope with two low capacity probes, connect one channel to pin 7 of V20 and the other channel to pin 7 of V21. Adjust the test oscilloscope to view both inputs simultaneously.

8) Adjust C77 and C82 for the best square wave pattern on the test oscilloscope.

9) Disconnect the dual channel test oscilloscope and set SWEEP MODE control to PRESET.

10) Set the Square Wave Generator to 100 kc.

11) Adjust the Square Wave Generator amplitude to obtain a horizontal deflection of approximately 5 centimeters. Use a sweep speed that will produce 2 or 3 cycles on the screen.

12) Adjust C84 and C88 plus C85 and C89 to obtain the best square wave pattern. Some high frequency ringing will be noted but should be disregarded when making these adjustments.

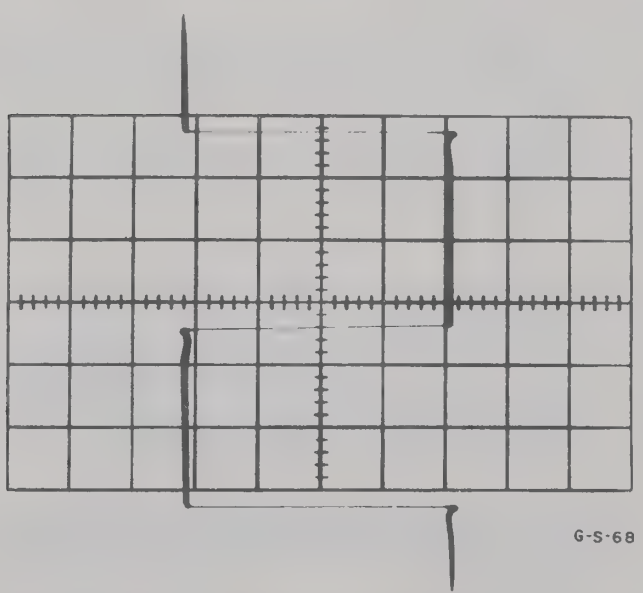

Figure 4-5. Horizontal Amplifier Response to 100 kc Square Wave

The following procedure is recommended:

a. Set capacitors C84 and C88 to the center of their adjustment range so they are set to approximately equal values.

b. Adjust for the best square wave pattern by rotating C84 and C88 each approximately the same amount to keep both capacitors as close to the same electrical value as possible.

c. Adjust Capacitors C85 and C89 for the best possible square wave pattern. Capacitors C85 and C89 are formed by metal straps around encapsulated resistors R219 and R224 respectively. Adjust by sliding straps along the resistors.

d. Repeat these steps as necessary to obtain the best possible square wave pattern.

13) Set the Square Wave Generator to 10 kc.

14) Set the HORIZ. SENSITIVITY switch to 1 VOLTS/CM and adjust the Square Wave Generator to produce a horizontal deflection of approximately 6 centimeters. Use a sweep speed that will display 2 or 3 cycles.

15) Adjust C75 to obtain the best square wave.

16) Set the Square Wave Generator to 100 kc, and adjust C86 for the best square wave.

17) Transfer the 75 ohm output of the Square Wave Generator to the EXT. SYNC. INPUT. Remove the cable from the 600 ohm output of the Square Wave Generator.

18) Connect an ℗ Model AC-21A Oscilloscope Probe to the EXT. HORIZ. INPUT, and connect the probe tip to the 600 ohm output of the Square Wave Generator. Ground the probe at the Square Wave Generator.

19) Set the Square Wave Generator to 1000 cycles and adjust the Oscilloscope Probe for the best possible square wave.

20) Switch the HORIZ. SENSITIVITY to 2 VOLTS/CM and set the Square Wave Generator amplitude for maximum or approximately 3 centimeters.

21) Adjust C71 and C72 to obtain the best possible square wave.

22) Disconnect all cables and test instruments.

4-9 MAIN VERTICAL AMPLIFIER

The main vertical amplifier is located on the left side of the instrument near the terminals on the neck of the cathode ray tube. Figure 4-6 shows the location of all adjustments on the amplifier. The following procedures apply to Main Vertical Amplifiers carrying Ⓗp Stock No. 150A-58B.

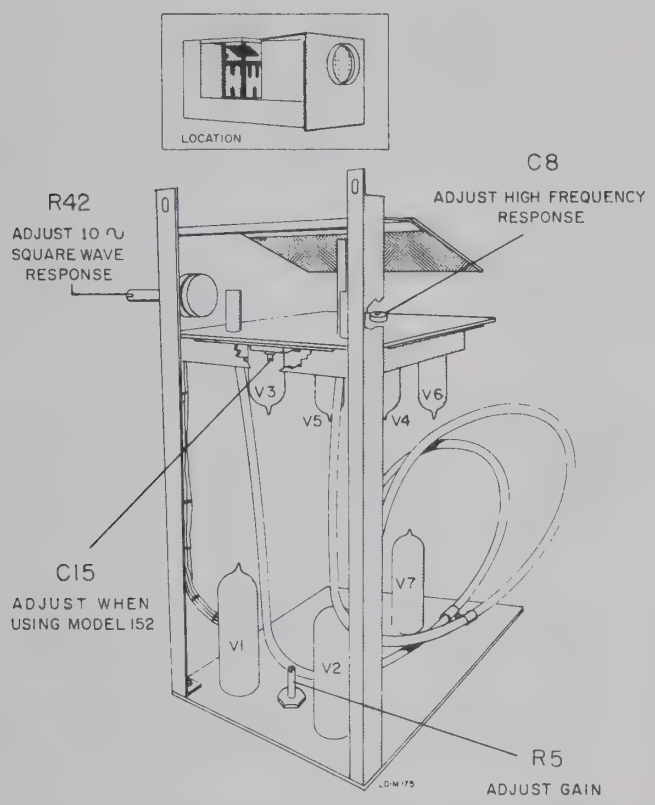

Figure 4-6. Main Vertical Amplifier Adjustments

A. ADJUST PLUG-IN AMPLIFIER

You should set the Balance and Calibration of the plug-in amplifier before continuing. Follow the instructions that are given in the Operating Instructions for the plug-in amplifier used.

B. TEST VERTICAL AMPLIFIER FOR LINEARITY

CAUTION

The voltmeter used for this check must not be grounded. The voltmeter case is 400 volts above ground.

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1) Connect a 400 cps signal to the plug-in vertical amplifier.

2) Connect an insulated ac voltmeter between the vertical deflection plates of the CRT.

3) Set the SWEEP MODE control full counter-clockwise but not on PRESET. Adjust the HORIZONTAL POSITION and VERTICAL POSITION controls to center the vertical trace. Keep intensity low.

4) Adjust VERTICAL POSITION to obtain a maximum voltmeter indication. The center of the pattern on the oscilloscope should be within 1 centimeter of the graticule vertical center. Set the amplitude of the input signal to obtain an indication of 1.00 volts on the voltmeter.

5) Adjust the trace to the top and bottom of the graticule. Note the voltmeter indication in both positions. The voltage should not drop below 0.95 volts. A voltage drop of more than 5% is usually caused by V5 and/or V6.

C. TEST VERTICAL AMPLIFIER FOR DRIFT

1) Center a low intensity spot on the face of CRT with the line voltage set at 102 volts.

2) Vary the power line voltage between 102 and 128 volts and closely observe spot for any shift in vertical position.

3) Spot shift should not exceed 0.5 centimeters. Excessive shift is usually caused by V1 and/or V2.

D. ADJUST VERTICAL AMPLIFIER GAIN

A 2 volt peak-to-peak (0.707 rms volt sine wave) input signal to the main vertical amplifier will produce a 4 centimeter peak-to-peak deflection when R5 is properly adjusted. Before starting the following procedure the voltage gain of the plug-in amplifier should be adjusted to exactly 10 (20 db) with the VOLT/CM selector set to ".05".

1) Connect a 400 cps sine wave signal to the vertical input of the plug-in amplifier.

2) Set the input signal level to 300 millivolts peak-to-peak (0.106 rms volt sine wave). Set the oscilloscope vertical VOLTS/CM to ".05" and VERNIER to "CAL".

3) Adjust R5 for a peak-to-peak deflection of 6 centimeters.

E. ADJUST VERTICAL AMPLIFIER SQUARE-WAVE RESPONSE

1) Set POLARITY to "POS. UP-AC", TRIGGER SLOPE to "+", SYNC. to "INT", and SWEEP TIME/CM to ".2 MICROSECONDS".

2) Set vertical VOLTS/CM at ".05" and vertical VERNIER at "CAL".

3) Connect a 100 kc square wave from the 75 ohm output of an hp Model 211A Square Wave Generator to the vertical input of the plug-in amplifier. Adjust the square wave generator output level to obtain a 6 centimeter peak-to-peak pattern.

4) Adjust C8 for the best rise time along the leading edge of the square wave. Crest variation should not exceed 0.12 centimeters (±2%).

5) Set the square wave generator to 10 cps.

6) Switch POLARITY to "POS. UP-DC" and SWEEP TIME/CM to "20 MILLISECONDS".

7) Adjust R42 for best possible square wave.

F. TEST INTERNAL SYNC AMPLIFIER

1) Connect a 1 kc sine wave signal to the vertical amplifier input.

2) Set the SYNC. selector to "INT". Adjust the oscilloscope controls to display the sine wave signal with a vertical deflection of 6 centimeters peak-to-peak.

3) Connect an ac voltmeter between ground and the long bare wire at the bottom of the sweep generator board. The voltage on this wire should be at least 5 volts rms, if not check V7 in the main vertical amplifier.

G. TEST VERTICAL AMPLIFIER BANDWIDTH

1) Connect a frequency response generator to the vertical input. Set this generator to 1 MC and adjust the amplitude to produce a peak-to-peak deflection of 4 centimeters. This deflection must be vertically centered on the graticule.

2) Increase the generator frequency until the peak-to-peak deflection has decreased to 2.8 centimeters. This is a drop of 3 db and should occur at a frequency above 10 mc. If this drop occurs at a frequency below 10 mc, clean the CRT deflection plate connecting pins and clips. In addition, dress the two yellow leads between the amplifier and the CRT neck connectors as far from each other and surrounding metal as possible.

If the above steps do not improve the bandwidth, it may be necessary to replace V5 and/or V6, or to recheck the plug-in amplifier frequency response in another oscilloscope.

4-10 SWEEP GENERATOR AND SYNC CIRCUITS

The Sweep Generator and Sync Circuits are located on the right side of the instrument on a swing out chassis. The chassis is held in place by a captive fastener located in the center of the board near the panel. The following adjustment procedures apply to sweep generator marked with hp Stock No. 150A-65L. Figure 4-7 locates the Sweep Generator adjustments.

A. ADJUST SYNC CIRCUITS

1) Connect a dc voltmeter between plate pins 1 and 6 of V8 inverter amplifier tube. These points each have a blue wire from the TRIGGER SLOPE switch connecting to them. The voltmeter must be insulated from ground.

2) Remove any external connection to EXT. SYNC. INPUT jacks and set SYNC. selector switch to EXT. AC.

3) Rotate the TRIGGER LEVEL control to obtain an indication of zero volts on the dc voltmeter.

4) The TRIGGER LEVEL control must not be moved until R66 and R72 have been adjusted.

5) Connect a 50 kc sine wave signal with an amplitude of 2 volts peak-to-peak to the EXT. SYNC. INPUT jack or terminals.

6) Calibrate the test oscilloscope with probe to have a vertical deflection sensitivity of 1 volt per centimeter.

7) Connect test oscilloscope probe to junction of R65 and arm of S2 TRIGGER SLOPE switch (use ac coupling). This point can be identified as the connector approximately midway between tubes V9 and V17 to which a green wire from the TRIGGER SLOPE switch is connected. If high frequency oscillations are present, rotate R66 maximum counterclockwise.

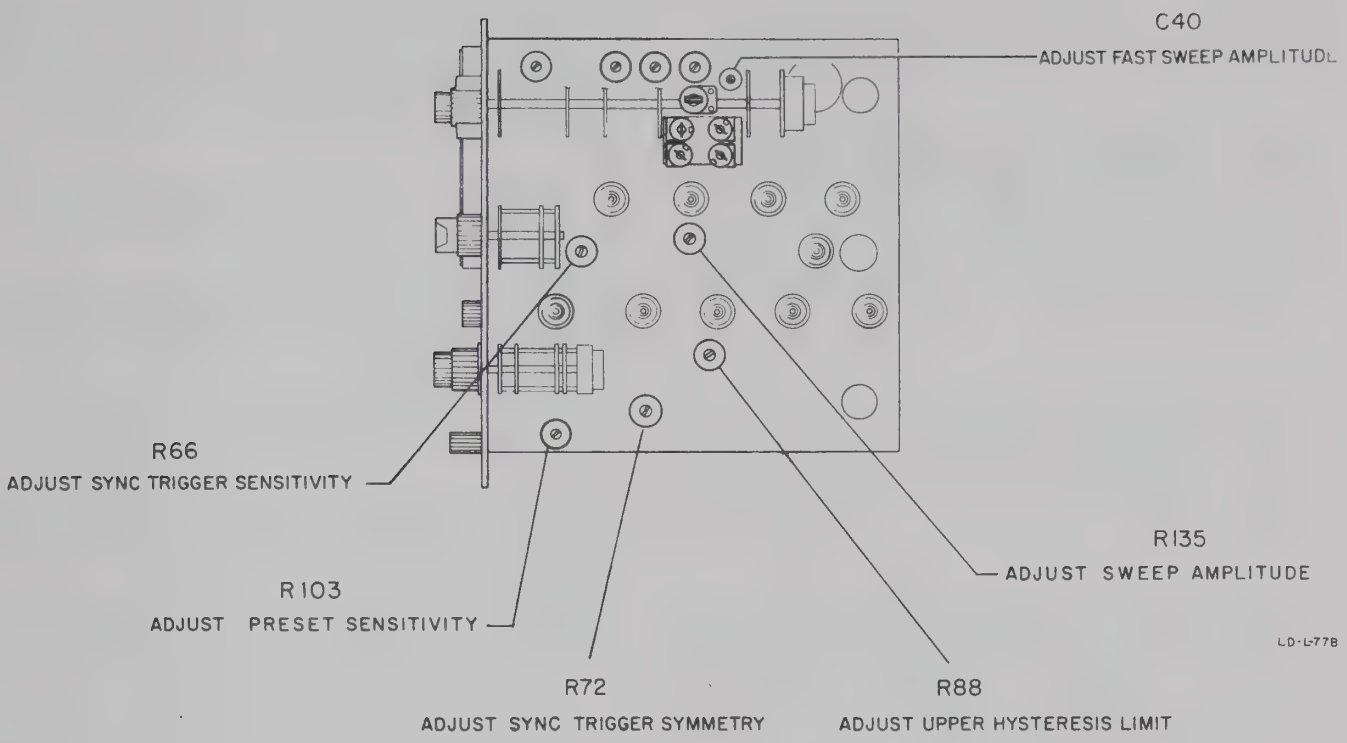


Figure 4-7. Sweep Generator Adjustments

8) Refer to Figures 4-7 and 4-8. Adjust potentiometer R66 and R72 for pips vertically spaced exactly 1 volt apart on the displayed sine wave. In addition, the pips must be exactly 0.5 volt above and below the center of the wave. The upper pip must be on the positive slope portion of the sine wave and the lower on the negative slope.

These two controls interact but pip vertical separation is primarily controlled by R66 and vertical position of both pips by R72. Repeated adjustments of both controls may be required.

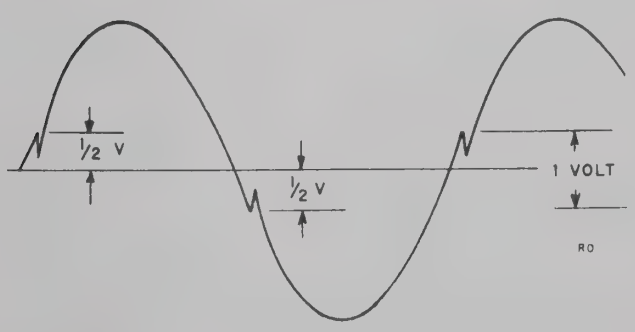


Figure 4-8. Sync Trigger Hysterisis Limits

If pips are not visible, set R66 as far clockwise as possible without introducing oscillation and then slowly rotate R72 until the pips appear.

B. ADJUST START-STOP TRIGGER AND SWEEP AMPLITUDE

1) With no input to the oscilloscope, set the SYNC selector to EXT. AC.

2) Set the SWEEP TIME/CM to 2 SECONDS/CM and rotate SWEEP MODE maximum clockwise to FREE RUN.

3) Connect a VTVM between ground and pin 2 of V10. The voltmeter indication will swing between approximately -40 and -15 volts.

4) Adjust R88 to obtain -15 volts at the end of the sweep. If unable to set R88, rotate R135 until R88 may be set properly.

5) Connect the VTVM between ground and pin 8 of V15. The violet wire terminated above V15 connects to pin 8.

6) The voltmeter indication will rise and fall with the sweep. Adjust R135 until the end of the sweep occurs between -110 and -115 volts.

7) Set the SWEEP TIME/CM to .1 MICROSECONDS, SWEEP VERNIER to CAL. and HORIZ. SENSITIVITY to X1. Connect the test oscilloscope to pin 8 of V15 through a low capacity probe and observe the sweep waveform. Adjust C40 for maximum undistorted amplitude. Undesirable distortion will appear at the most negative point on the waveform.

C. ADJUST SWEEP PRESET

1) Disconnect any external vertical input to oscilloscope. Set SWEEP TIME/CM switch to ".1 MILLISECONDS" and SWEEP MODE control maximum counterclockwise to "PRESET". Set SYNC. selector to "INT".

2) Connect the voltmeter between ground (+) and pin 2 (-) of V10. Slowly adjust R103 until the sweep generator begins to free-run. The voltmeter indication will increase, as R103 is rotated, to a maximum and then suddenly drop, when the sweep generator begins to free-run.

Repeat this several times and note the average maximum voltmeter indication. The exact value of this voltage is not critical and will vary with individual characteristics of tubes V10 and V11.

3) Set R103 to give a voltmeter indication exactly 1.5 volts less negative than the maximum noted before the sweep began to free-run. For example; if the maximum voltage noted was -37 volts, R103 should be set for -35.5 volts.

D. ADJUST SWEEP CALIBRATION

1) Set the SWEEP TIME/CM switch to ".1 MICROSECONDS", VERNIER to "CAL", HORIZ. SENSITIVITY to "X5" and the SWEEP MODE maximum clockwise to "FREE RUN".

2) Connect the output of a Marker Generator to the vertical input.

3) Set the Marker Generator for a 10 mc sine wave output and adjust the oscilloscope controls for a steady display 5 to 6 centimeters high.

4) Adjust C67 so two cycles of the sine wave are 10 centimeters long.

5) Set the HORIZONTAL SENSITIVITY switch to "X1".

6) Adjust C78, located on the Horizontal Amplifier chassis, so each cycle of the sine wave is exactly one centimeter long. If the total sweep length is less than 10 centimeters, check the sweep length adjustment C40.

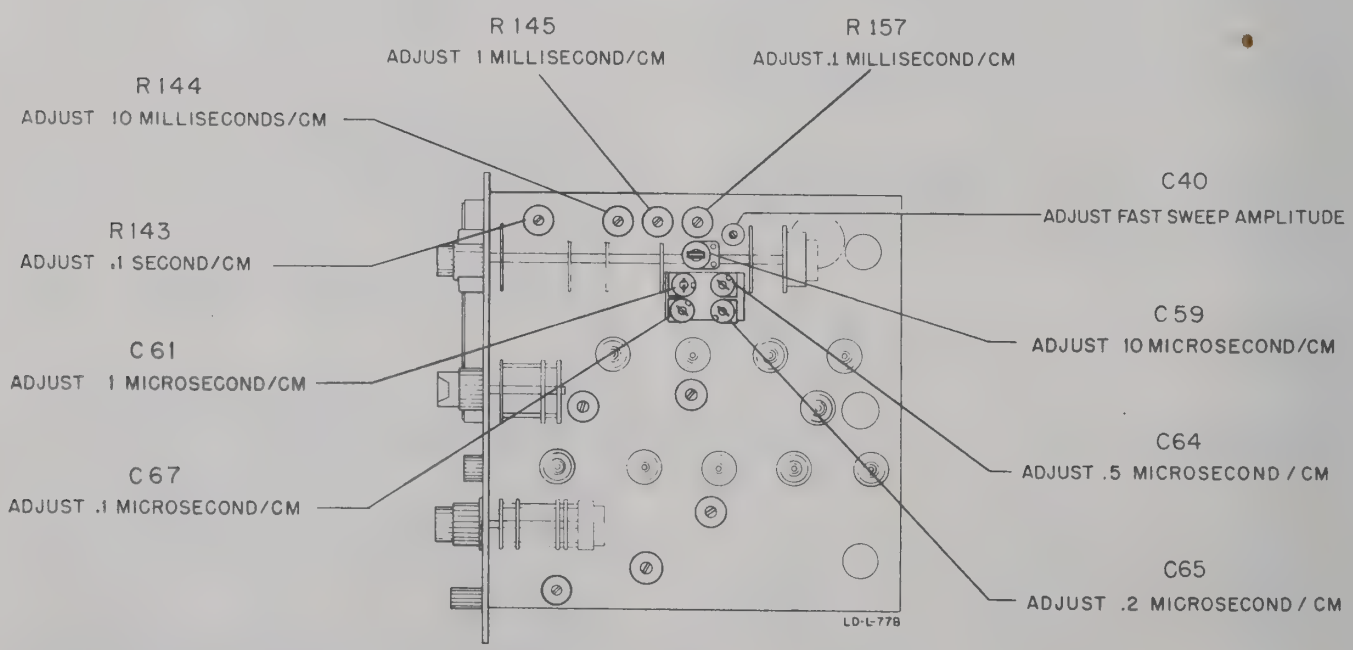


Figure 4-9. Sweep Calibration Adjustments

7) Set the Marker Generator for a 5 mc sine wave.

8) Set the SWEEP TIME/CM to ".2 MICROSECONDS" and adjust C65 so each cycle of the sine wave is exactly one centimeter long.

9) Set the Marker Generator for 1 microsecond pips and rotate the SWEEP MODE into "PRESET".

10) Set the SWEEP TIME/CM switch to ".5 MICROSECONDS" and adjust C64 until the pips are exactly 2 centimeters apart.

11) Set the SWEEP TIME/CM switch to "1 MICROSECONDS" and adjust C61 to space the pips exactly 1 centimeter apart.

12) Set the Marker Generator for 10 microsecond pips.

13) Set the SWEEP TIME/CM switch to "10 MICROSECONDS" and adjust C59 to space the pips exactly 1 centimeter apart.

14) Set the Marker Generator for 100 microsecond pips.

15) Set the SWEEP TIME/CM switch to ".1 MILLISECONDS" and adjust R157 to space the pips exactly 1 centimeter apart.

16) Set the Marker Generator for 5 microsecond pips.

17) Set the HORIZONTAL SENSITIVITY switch to "X5", "X10", "X50", and "X100". This should produce pips spaced every .25, .5, 2.5, and 5 centimeters.

If the expanded sweep ranges are out of calibration, set the HORIZONTAL SENSITIVITY to X100 and adjust R213, located on the Horizontal Amplifier chassis, to space the pips exactly 5 centimeters apart.

Return the HORIZONTAL SENSITIVITY switch to "X1".

18) Set the Marker Generator for 1 millisecond pips.

19) Rotate the sweep VERNIER control from one extreme to the other. Pip spacing should change from 10 centimeters to between 2.9 and 3.3 centimeters. If the spacing is less than 2.9 centimeters, connect a 120,000 ohm or higher resistor in parallel with the VERNIER control. If the spacing is more than 3.3 centimeters, reduce the value of R147 which is in series with the VERNIER control.

20) Set the SWEEP TIME/CM switch to "1 MILLISECONDS" and adjust R145 to space the pips exactly 1 centimeter apart.

21) Set the Marker Generator for 10 millisecond pips.

22) Set the SWEEP TIME/CM switch to "10 MILLISECONDS" and adjust R144 to space the pips exactly 1 centimeter apart.

23) Set the Marker Generator for 100 miilisecond (0.1 second) pips.

24) Set the SWEEP TIME/CM switch to ".1 SECOND" and adjust R143 to space the pips exactly 1 centimeter apart.

E. TEST SINGLE SWEEP OPERATION

1) Set the SWEEP TIME/CM to "10 MILLISECONDS" or longer.

2) Set TRIGGER LEVEL to "0" and SYNC. to "INT". Apply a signal with a frequency of 1 mc or below. Adjust signal amplitude to obtain 4 centimeters peak-to-peak vertical deflection.

3) Set the NORMAL-SINGLE SWEEP (SWEEP RESET, INT-EXT) switch to "SINGLE SWEEP (EXT)".

4) Rotate the SWEEP MODE control maximum clockwise, then counterclockwise into PRESET. A single sweep will be obtained on switching into PRESET.

5) Rotate SWEEP MODE off of PRESET, lamp I6 should go on. Continued clockwise rotation of this control should produce one sweep after which lamp I6 will be off. Leave the SWEEP MODE control rotated maximum clockwise.

The spot should return to the sweep starting point. This may be determined by temporarily increasing intensity.

6) It should be possible to complete steps 4 and 5 with the SWEEP TIME/CM switch in any position. As the sweep time is shortened it becomes progressively difficult to see tha trace.

7) Rotate SWEEP MODE counterclockwise toward PRESET, a sweep should not be obtained until the control is placed in PRESET. If a sweep is obtained, replace V17 or lower the value of R110 (166K, ±1%)

by connecting a 2.7 megohm or lower resistor in parallel with it. Use as high a resistor value as possible that will eliminate this extra sweep.

THE REMAINING STEPS CHECK SINGLE SWEEP OPERATION BY USING AN EXTERNAL PULSE TO RESET THE SWEEP.

8) Connect the positive sync output from an hp Model 212A Pulse Generator to oscilloscope vertical input.

9) Set the Pulse Generator for a positive output pulse and connect output to oscilloscope RESET connector.

10) Set the Pulse Generator for a 500 per second repetition rate and a 3 microsecond pulse width.

11) Set the NORMAL SINGLE SWEEP (SWEEP RESET, INT-EXT) switch to "NORMAL (INT)", the TRIGGER SLOPE to "+", and SWEEP TIME/CM to ".2 MICROSECONDS". Adjust vertical VOLTS/CM to "20" with VERNIER at "CAL".

12) Set TRIGGER LEVEL to obtain a display of the 212A sync pulse.

13) Set the SINGLE SWEEP-NORMAL switch for SINGLE SWEEP and the 212A pulse position control for maximum delay.

14) Advance the Pulse Generator output from minimum until the sync output pulse is displayed on the oscilloscope. Usually the amplitude of this pulse will be approximately 10 volts peak-to-peak. The start of the oscilloscope sweep and the start of the pulse should approximately coincide and should not change with a change in the Pulse Generator pulse delay time.

15) Disconnect all instruments and return the SINGLE SWEEP-NORMAL switch to "NORMAL".

F. TEST OPERATION OF MAGNIFIED AND UNCALIBRATED LIGHTS

1) The SWEEP MAGNIFIED light should be ON with the HORIZONTAL SENSITIVITY control in the "X5", "X10", "X50", and "X100" positions.

2) The MAGNIFIER UNCALIBRATED light should be ON with SWEEP TIME/CM and the HORIZONTAL SENSITIVITY control set to the combinations shown in Table 4-5.

3) If lights fail to operate as above, switches may be defective or connectors from SWEEP TIME/CM and HORIZONTAL SENSITIVITY switches may be disconnected or transposed.

TABLE 4-5. MAGNIFIER UNCALIBRATED LIGHT

HORIZONTAL SENSITIVITY	.1	.2	.5	1	2
X10	ON				
X50	ON	ON	ON	ON	
X100	ON	ON	ON	ON	ON

SWEEP TIME - MICROSECOND/CM

G. TEST GATE OUTPUT WAVEFORM

1) Set the SWEEP TIME/CM switch to .1 MICROSECONDS and the SWEEP MODE to FREE RUN.

2) Connect a test oscilloscope through a low capacity probe to the GATE OUTPUT connector. The test oscilloscope should be set for positive up deflection.

3) This waveform should be a nonsymmetrical square wave with a peak-to-peak amplitude of 20 to 30 volts. Ripple on the top of the waveform should not exceed 2% of the total amplitude.

4) The square wave rise time should be less than approximately 0.15 microseconds, and the decay time should be less than approximately 0.7 microseconds.

5) Overshoot in the waveform may be due to CR3 being defective.

H. TEST SWEEP OUTPUT WAVEFORM

1) Attach the test oscilloscope to the SWEEP OUTPUT connector.

2) The sweep output waveform should have a peak amplitude of at least 40 volts and may be considerably higher.

SCHEMATIC DIAGRAM NOTES

1. Heavy solid line shows main signal path; heavy dashed line shows control, secondary signal, or feedback path.

2. Heavy box indicates front-panel engraving; light box indicates chassis marking.

3. Arrows on potentiometers indicate clockwise rotation as viewed from the round shaft end, counter-clockwise from the rectangular shaft end.

4. Resistance values in ohms, inductance in microhenries, and capacitance in micromicrofarads unless otherwise specified.

5. Rotary switch schematics are electrical representations; for exact switching details refer to the switch assembly drawings.

6. Relays shown in condition prevailing during normal instrument operation.

7. ‡ indicates a selected part. See parts list.

8. Interconnecting parts and assemblies are shown on cable diagram.

9. * Value adjusted at factory. Part may be omitted.

VOLTAGE AND RESISTANCE DIAGRAM NOTES

1. Each tube socket terminal is numbered and lettered to indicate the tube element and pin number, as follows:

*	=	no tube element	P	=	plate
H	=	heater	T	=	target (plate)
K	=	cathode	R	=	reflector or repeller
G	=	control grid	A	=	anode (plate)
Sc	=	screen grid	S	=	spade
Sp	=	suppressor grid	Sh	=	shield
Hm	=	heater mid-tap	NC	=	no external connection to socket
IS	=	internal shield	Δ	=	indefinite reading due to circuit (see 2.)

The numerical subscript to tube-element designators indicates the section of a multiple-section tube; the letter subscript to tube-element designators indicates the functional difference between like elements in the same tube section, such as t for triode and p for pentode.

A socket terminal with an asterisk may be used as a tie point and may have a voltage and resistance shown.

2. Voltages values shown are for guidance; values may vary from those shown due to tube aging or normal differences between instruments. Resistance values may vary considerably from those shown when the circuit contains potentiometers, crystal diodes, or electrolytic capacitors.

3. Voltage measured at the terminal is shown above the line, resistance below the line; measurements made with an electronic multimeter, from terminal to chassis ground unless otherwise noted.

4. A solid line between socket terminals indicates a connection external to the tube between the terminals; a dotted line between terminals indicates a connection inside the tube. Voltage and resistance are given at only one of the two joined terminals.

MAIN VERTICAL AMPLIFIER

VOLTAGE – RESISTANCE DIAGRAM

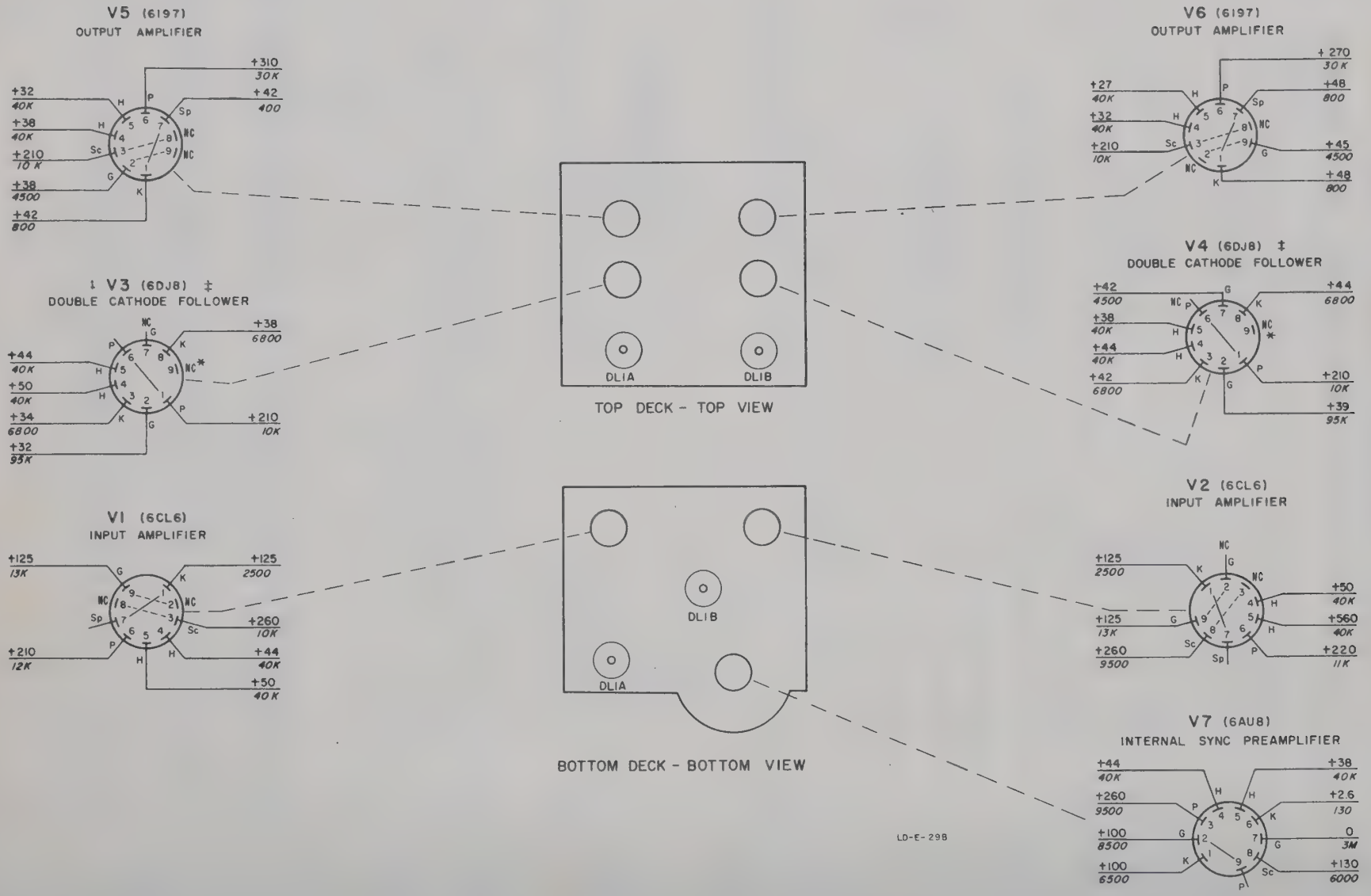
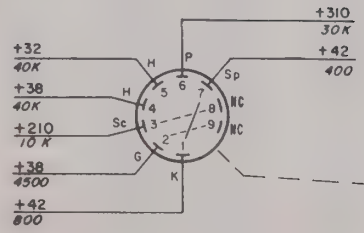


FIGURE 4-10
MAIN VERTICAL AMPLIFIER

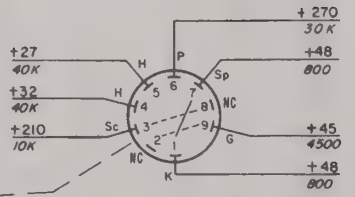
MAIN VERTICAL AMPLIFIER

VOLTAGE – RESISTANCE DIAGRAM

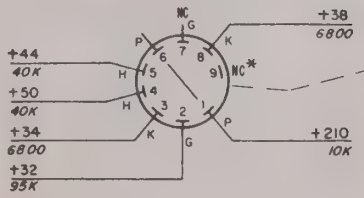
V5 (6197)
OUTPUT AMPLIFIER

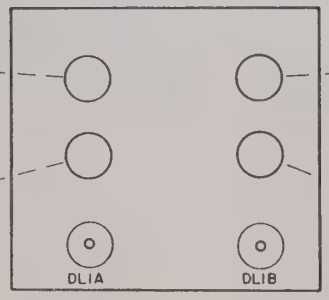


V6 (6197)
OUTPUT AMPLIFIER



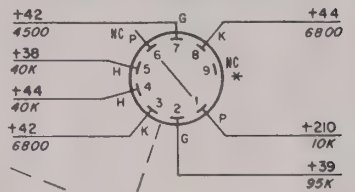
‡ V3 (6DJ8) ‡
DOUBLE CATHODE FOLLOWER



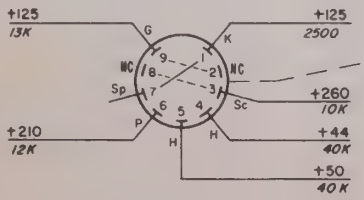


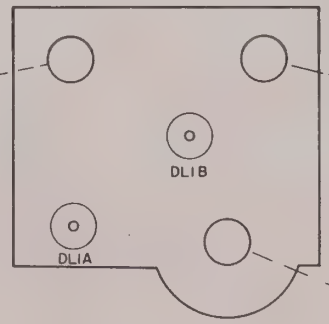
TOP DECK – TOP VIEW

V4 (6DJ8) ‡
DOUBLE CATHODE FOLLOWER



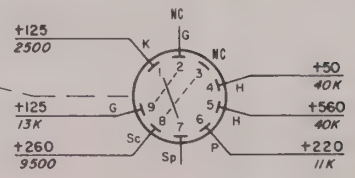
V1 (6CL6)
INPUT AMPLIFIER



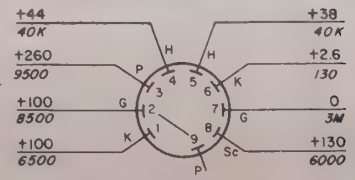


BOTTOM DECK – BOTTOM VIEW

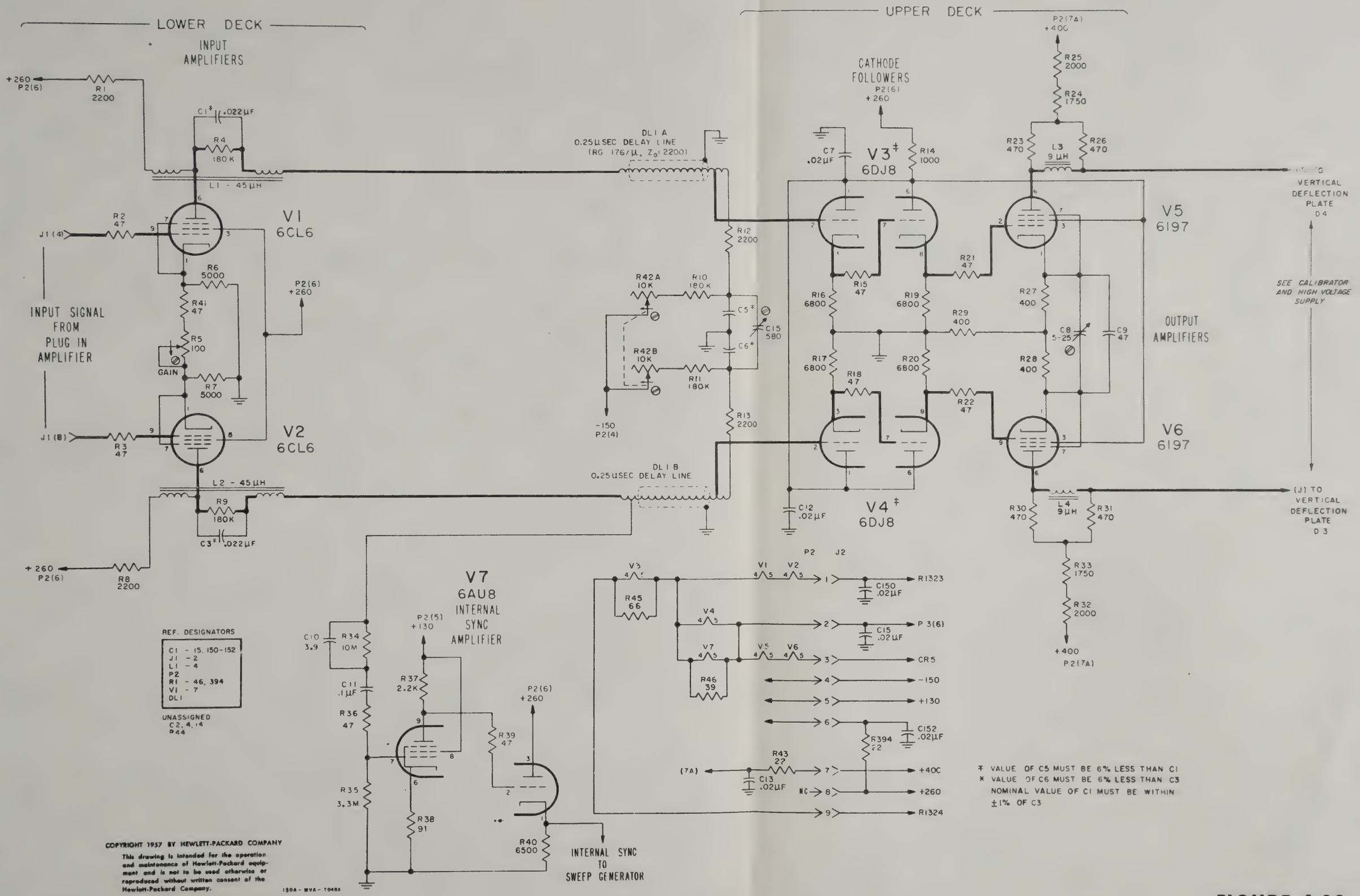
V2 (6CL6)
INPUT AMPLIFIER



V7 (6AU8)
INTERNAL SYNC PREAMPLIFIER



LD-E-298



REF. DESIGNATORS

C1 - 15, 150-152
J1 - 2
L1 - 4
P2
R1 - 46, 394
V1 - 7
DL1

UNASSIGNED
C2, 4, 14
R44

‡ VALUE OF C5 MUST BE 6% LESS THAN C1
* VALUE OF C6 MUST BE 6% LESS THAN C3
NOMINAL VALUE OF C1 MUST BE WITHIN ±1% OF C3

130A - MVA - 1048A

FIGURE 4-10
MAIN VERTICAL AMPLIFIER

SWEEP GENERATOR

VOLTAGE-RESISTANCE DIAGRAM (VIEWED FROM OUTSIDE)

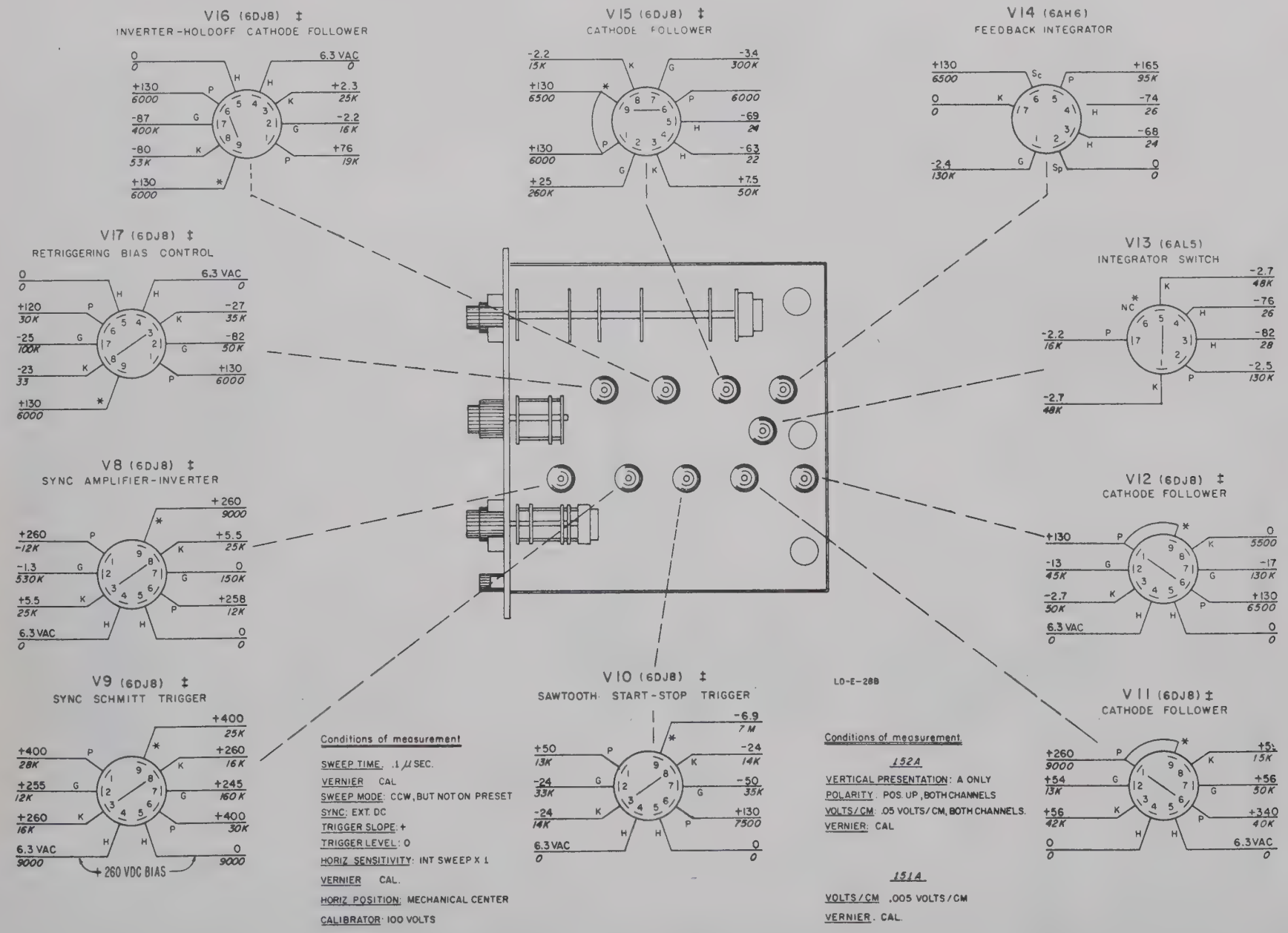
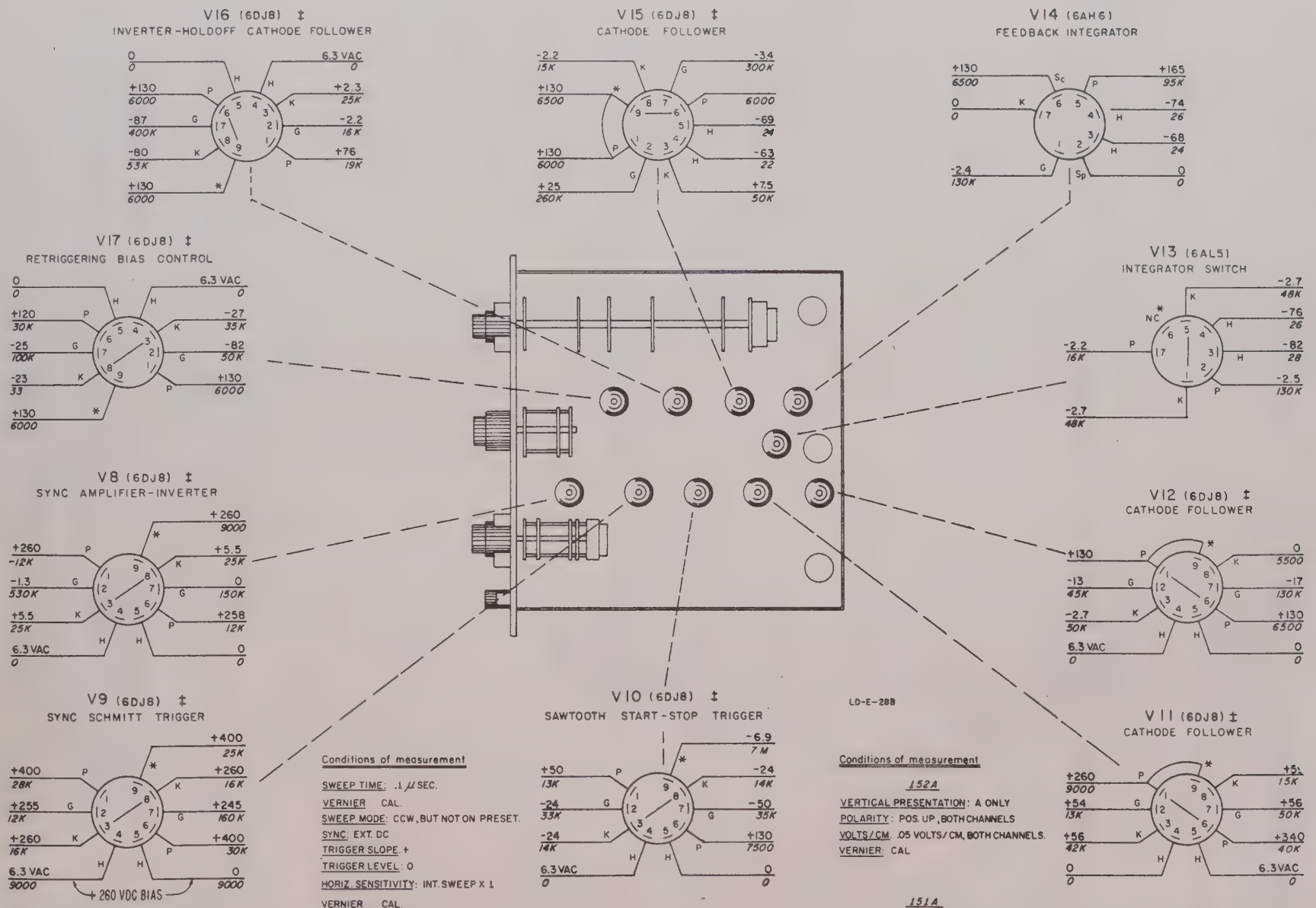


FIGURE 4-11
SWEEP GENERATOR

SWEEP GENERATOR

VOLTAGE-RESISTANCE DIAGRAM (VIEWED FROM OUTSIDE)



LD-E-288

Conditions of measurement

SWEEP TIME: .1 μ SEC.
VERNIER CAL.
SWEEP MODE: CCW, BUT NOT ON PRESET.
SYNC: EXT. DC
TRIGGER SLOPE: +
TRIGGER LEVEL: 0
HORIZ. SENSITIVITY: INT. SWEEP X 1
VERNIER CAL.
HORIZ. POSITION: MECHANICAL CENTER
CALIBRATOR: 100 VOLTS

Conditions of measurement

152A

VERTICAL PRESENTATION: A ONLY
POLARITY: POS. UP, BOTH CHANNELS
VOLTS/CM: .05 VOLTS/CM, BOTH CHANNELS.
VERNIER: CAL

151A

VOLTS/CM .005 VOLTS/CM
VERNIER: CAL

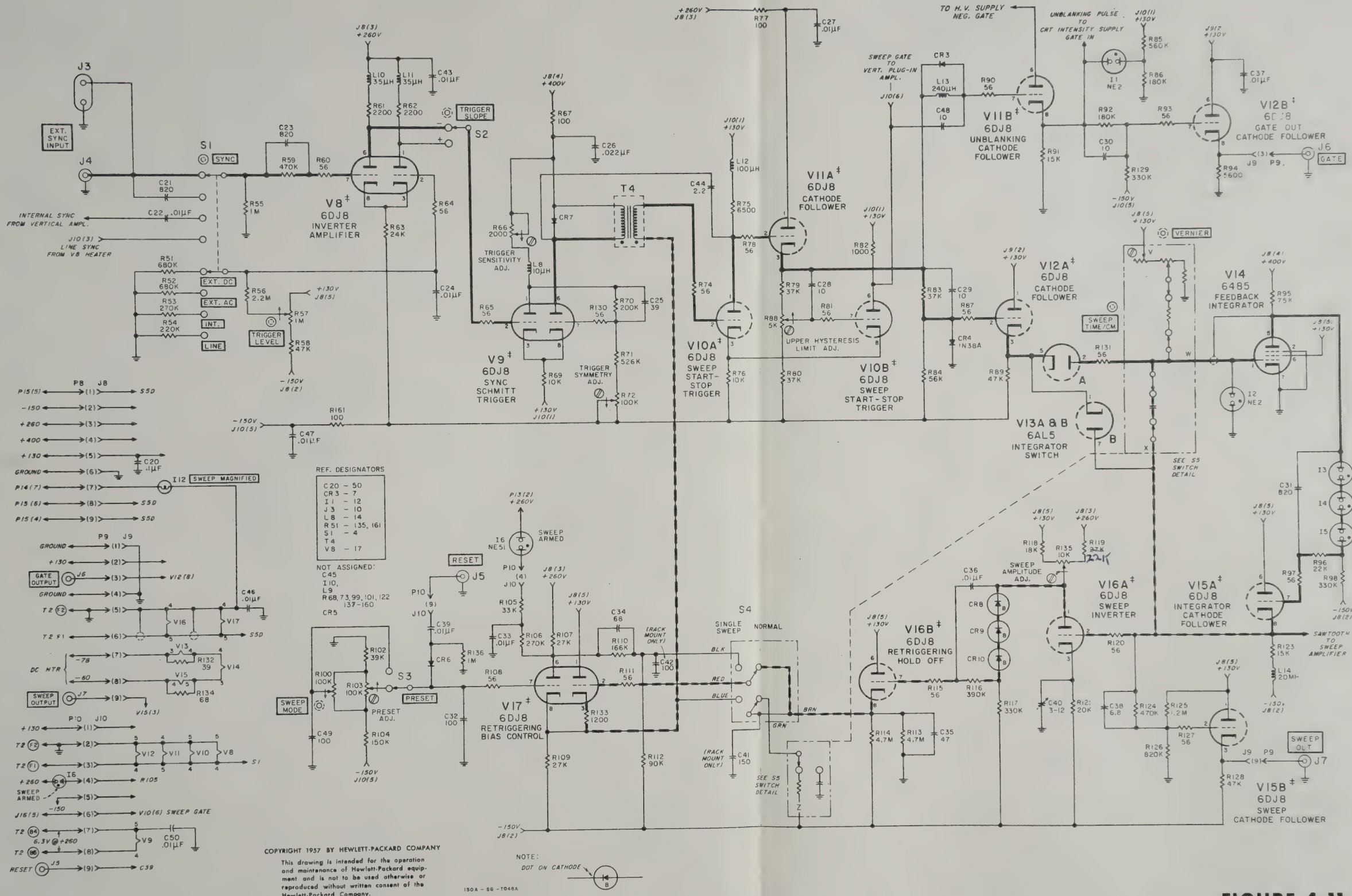
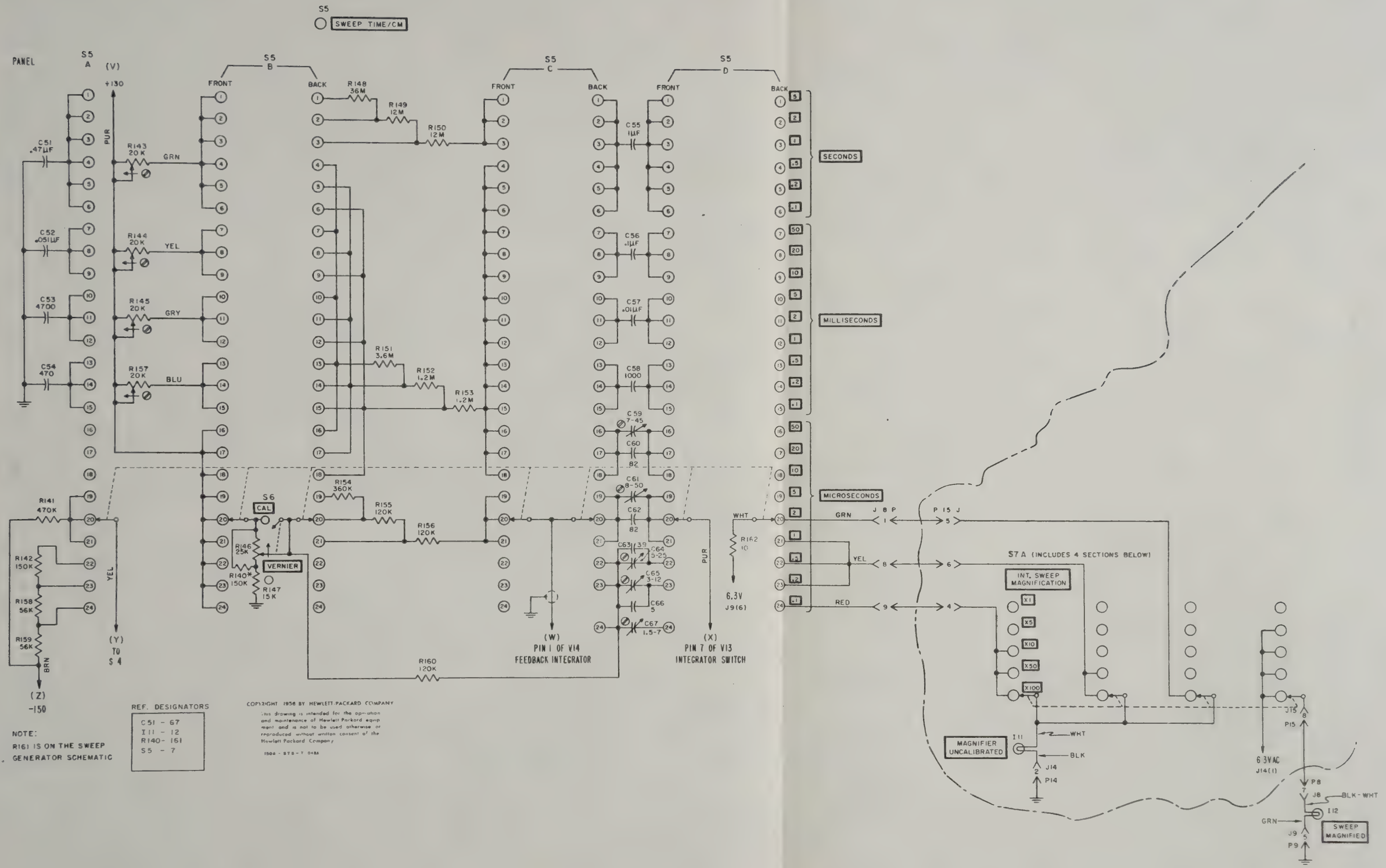


FIGURE 4-11
SWEEP GENERATOR

FIGURE 4-12
SWEEP TIME/CM SWITCH DETAIL



NOTE:
R161 IS ON THE SWEEP GENERATOR SCHEMATIC

REF. DESIGNATORS

C51 - 67
I11 - 12
R140 - 161
S5 - 7

1504 - 878 - Y 0486

FIGURE 4-12
SWEEP TIME/CM SWITCH DETAIL

HORIZONTAL AMPLIFIER

VOLTAGE - RESISTANCE DIAGRAM (VIEWED FROM OUTSIDE)

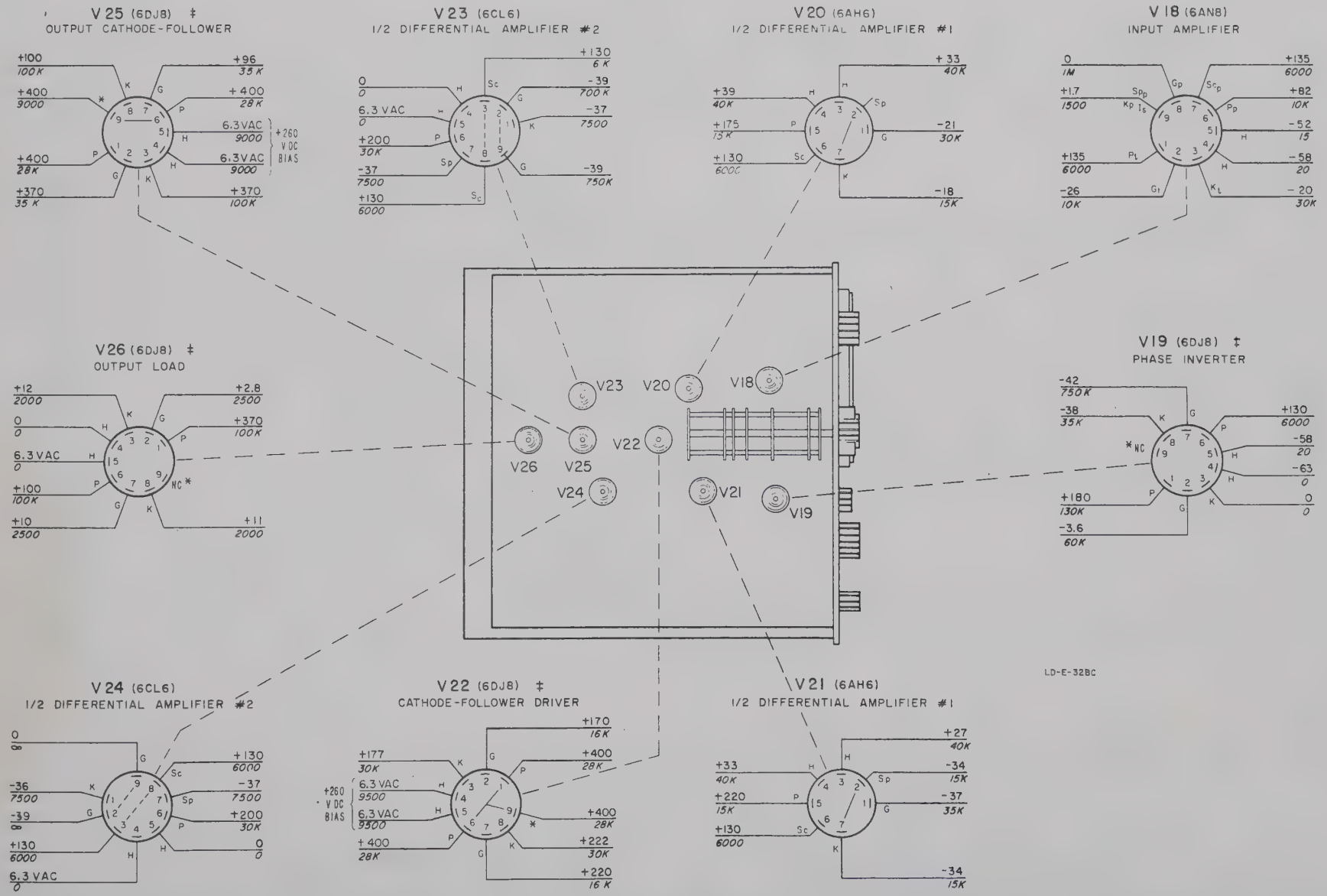
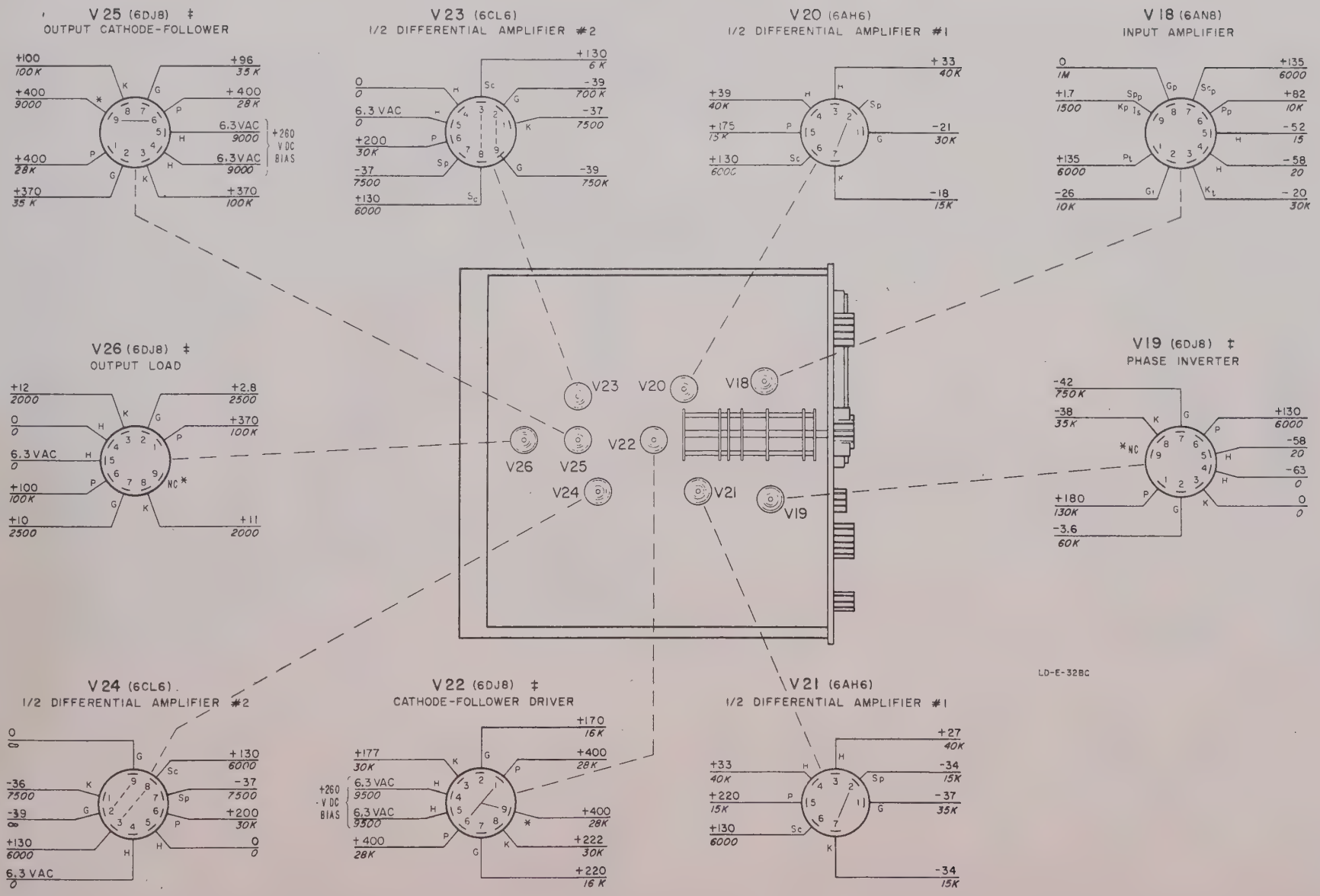


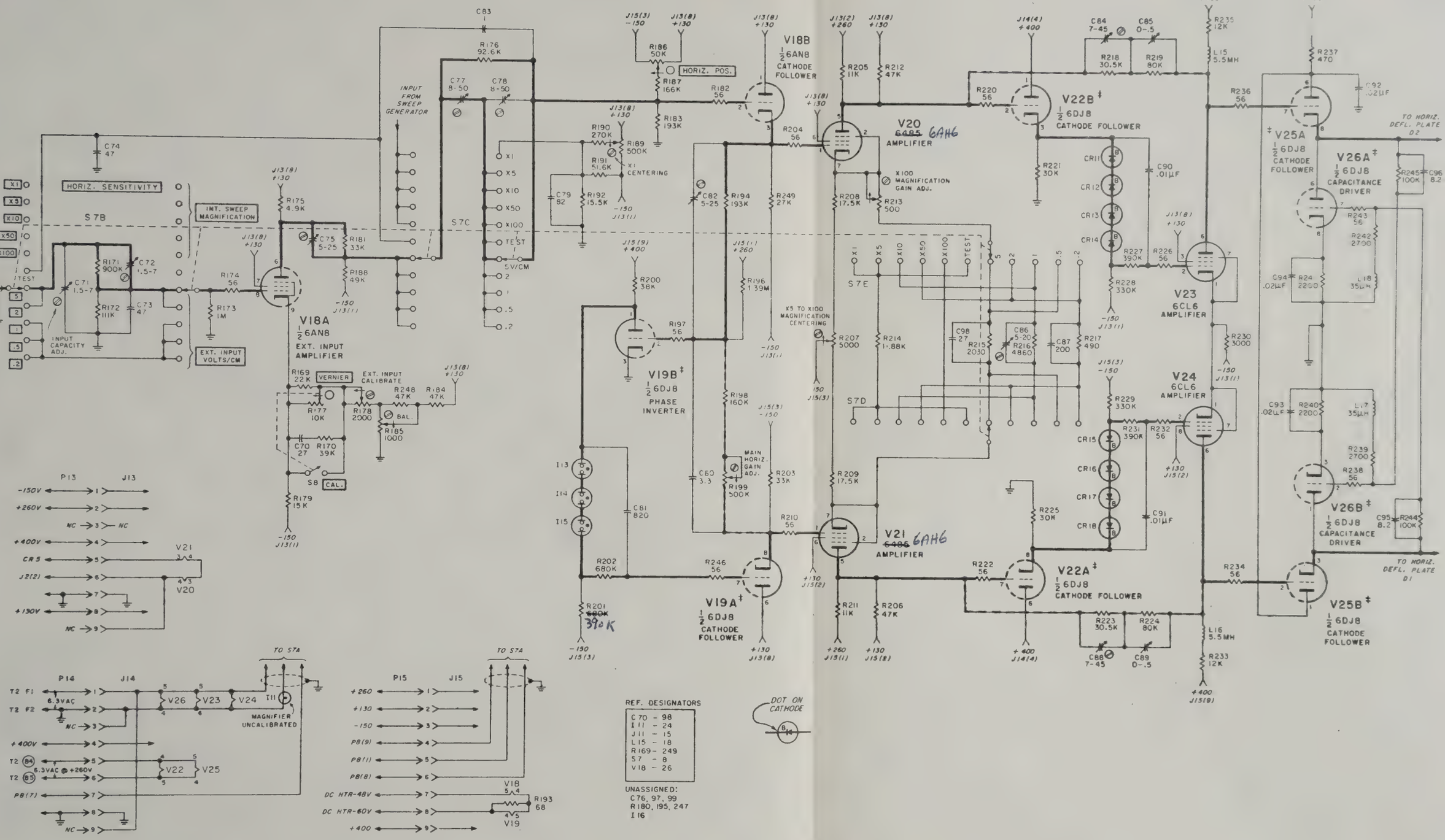
FIGURE 4-13
HORIZONTAL AMPLIFIER

HORIZONTAL AMPLIFIER

VOLTAGE - RESISTANCE DIAGRAM (VIEWED FROM OUTSIDE)



LD-E-32BC



150A - HA - T048A

FIGURE 4-13
HORIZONTAL AMPLIFIER

CALIBRATOR AND HIGH VOLTAGE REGULATED POWER SUPPLY

VOLTAGE – RESISTANCE DIAGRAM

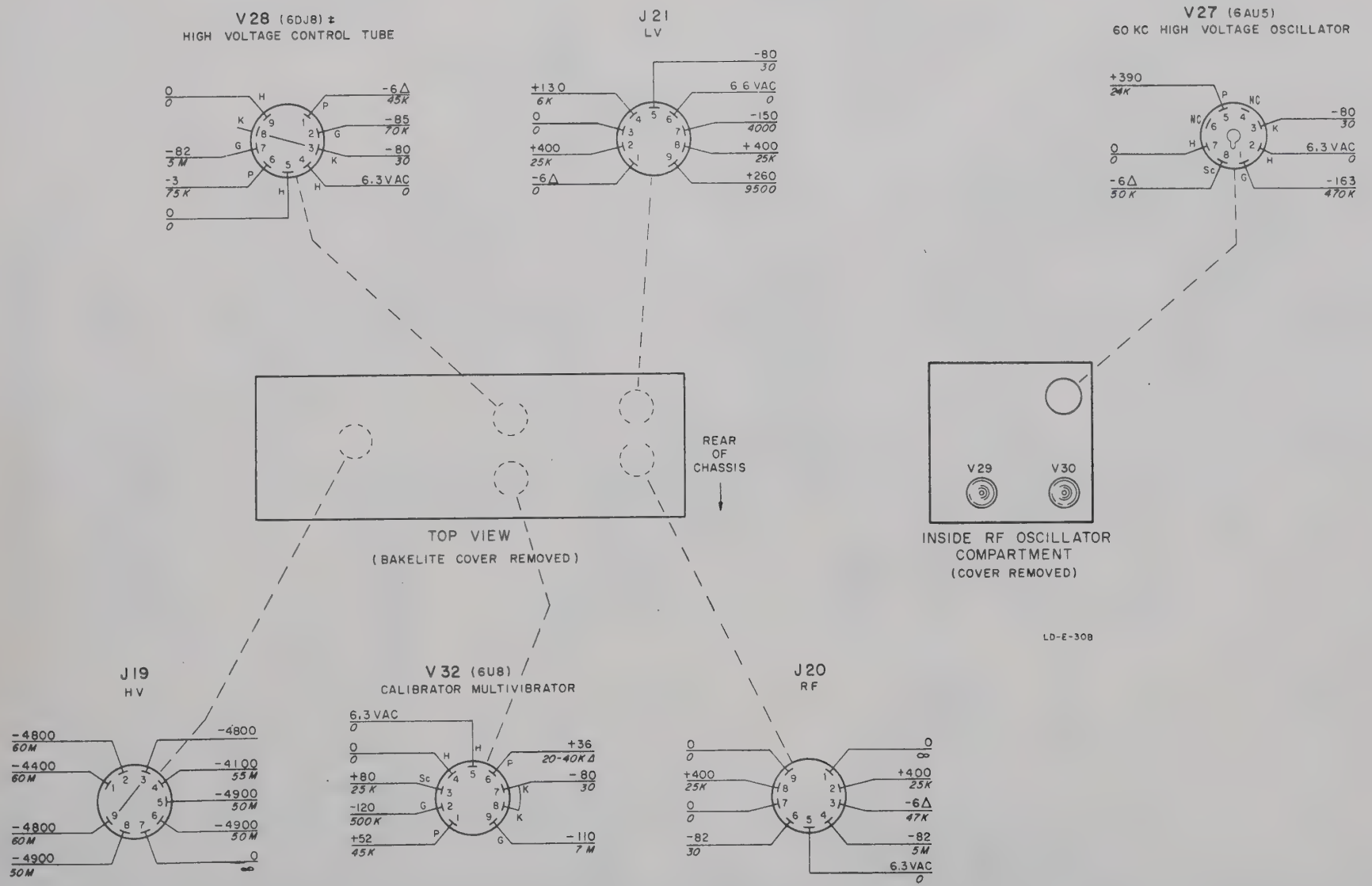
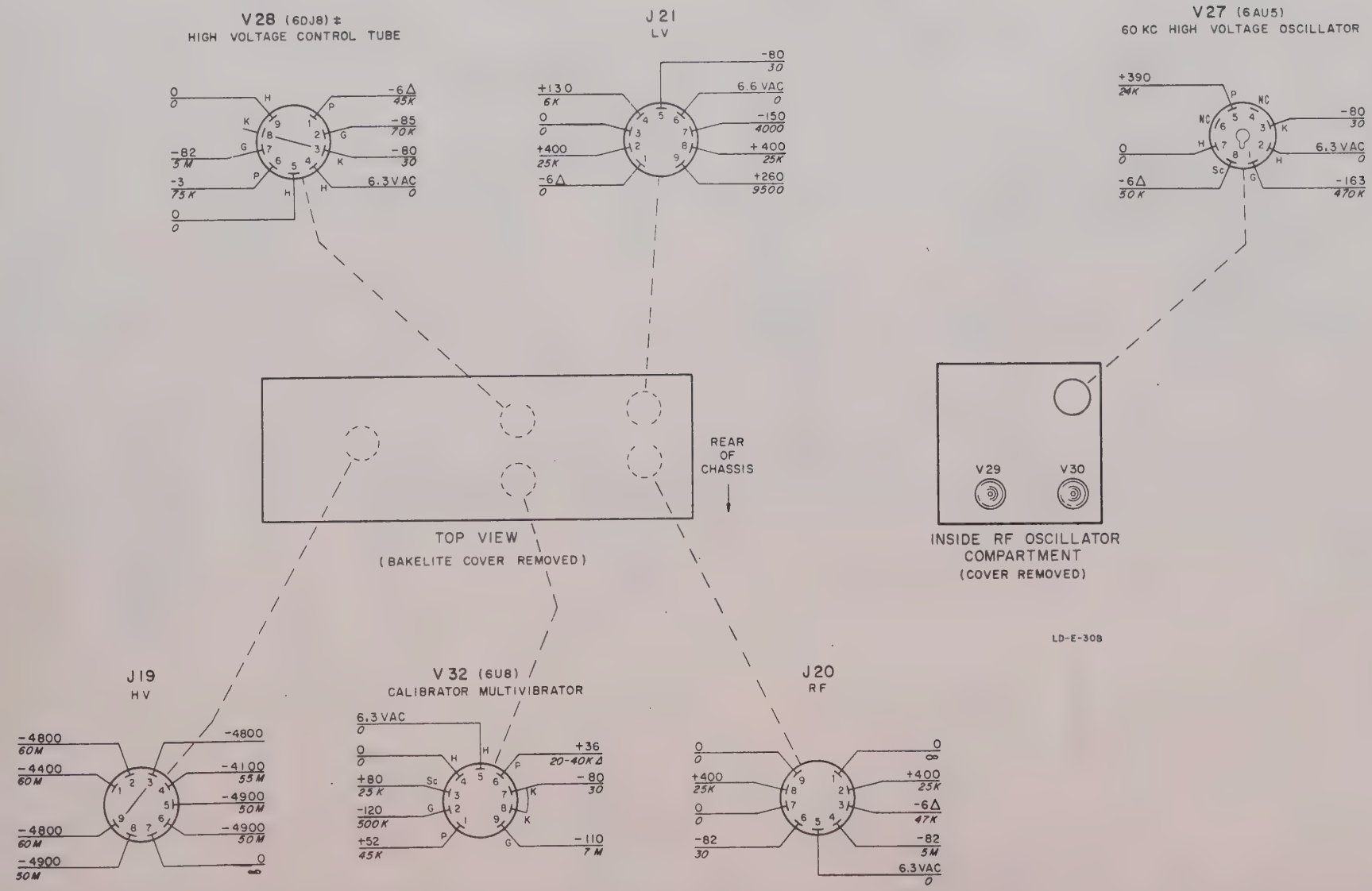


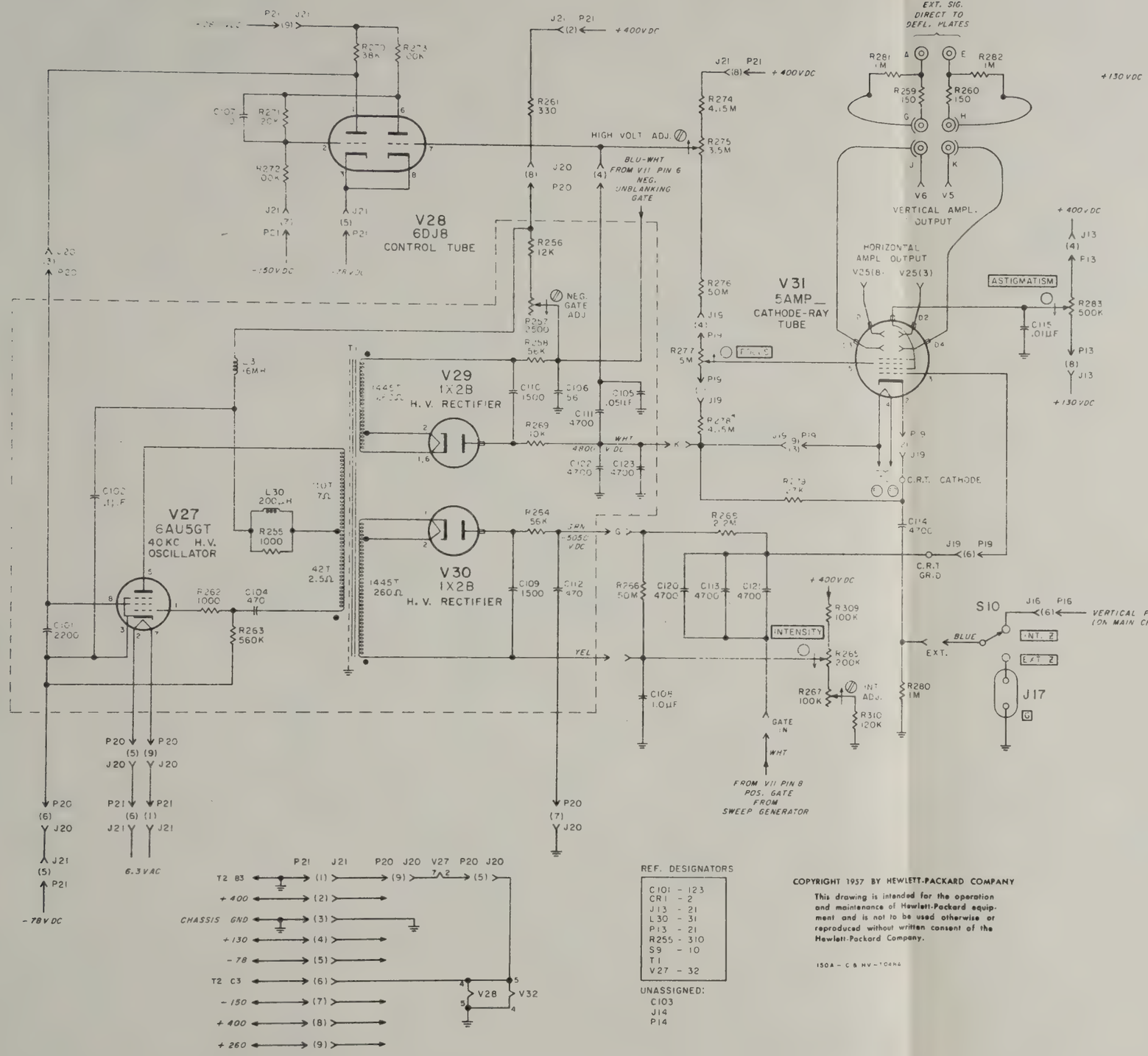
FIGURE 4-14
CALIBRATOR AND
HIGH VOLTAGE SUPPLY

CALIBRATOR AND HIGH VOLTAGE REGULATED POWER SUPPLY

VOLTAGE – RESISTANCE DIAGRAM



HIGH VOLTAGE SUPPLY & CRT CIRCUIT



REF. DESIGNATORS

C101 - 123
CR1 - 2
J13 - 21
L30 - 31
P13 - 21
R255 - 310
S9 - 10
T1
V27 - 32

UNASSIGNED:
C103
J14
P14

150A - C & HV - 104R2

CALIBRATOR

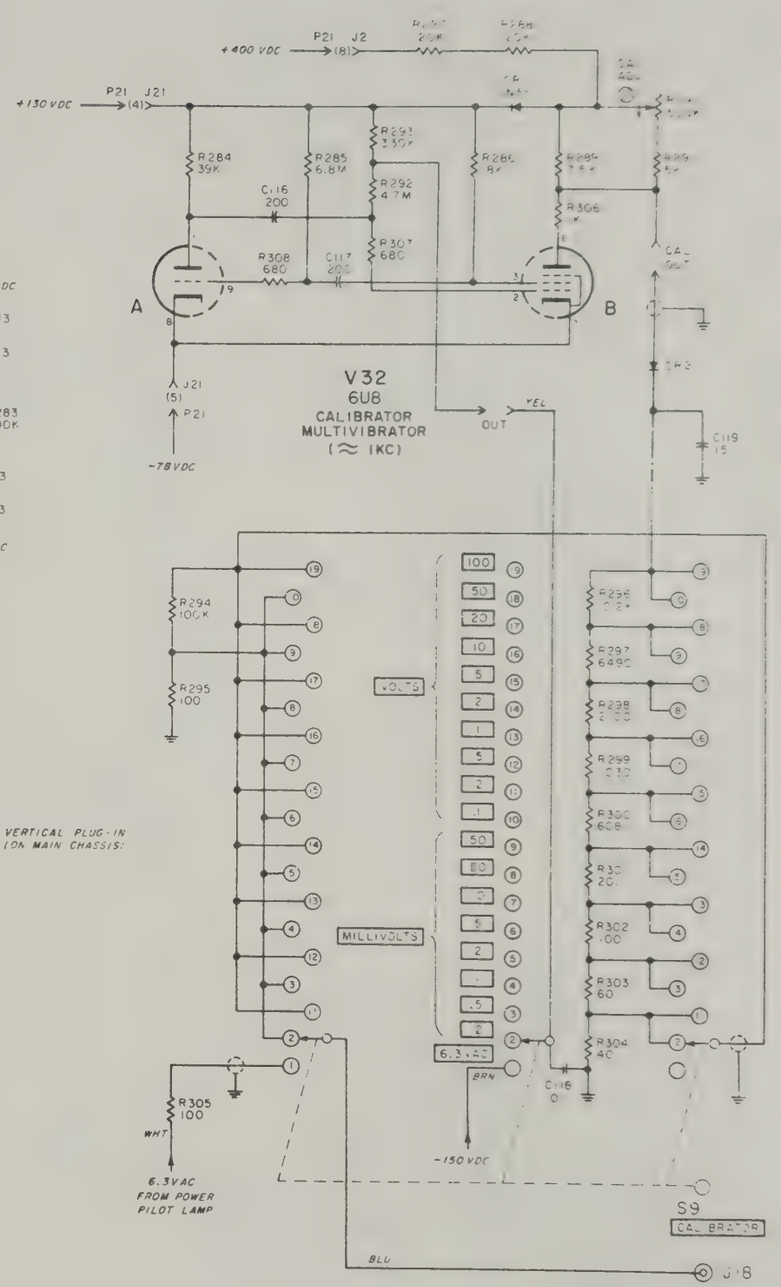


FIGURE 4-14
CALIBRATOR AND HIGH VOLTAGE SUPPLY

LOW VOLTAGE POWER SUPPLY

VOLTAGE – RESISTANCE DIAGRAM (VIEWED FROM OUTSIDE)

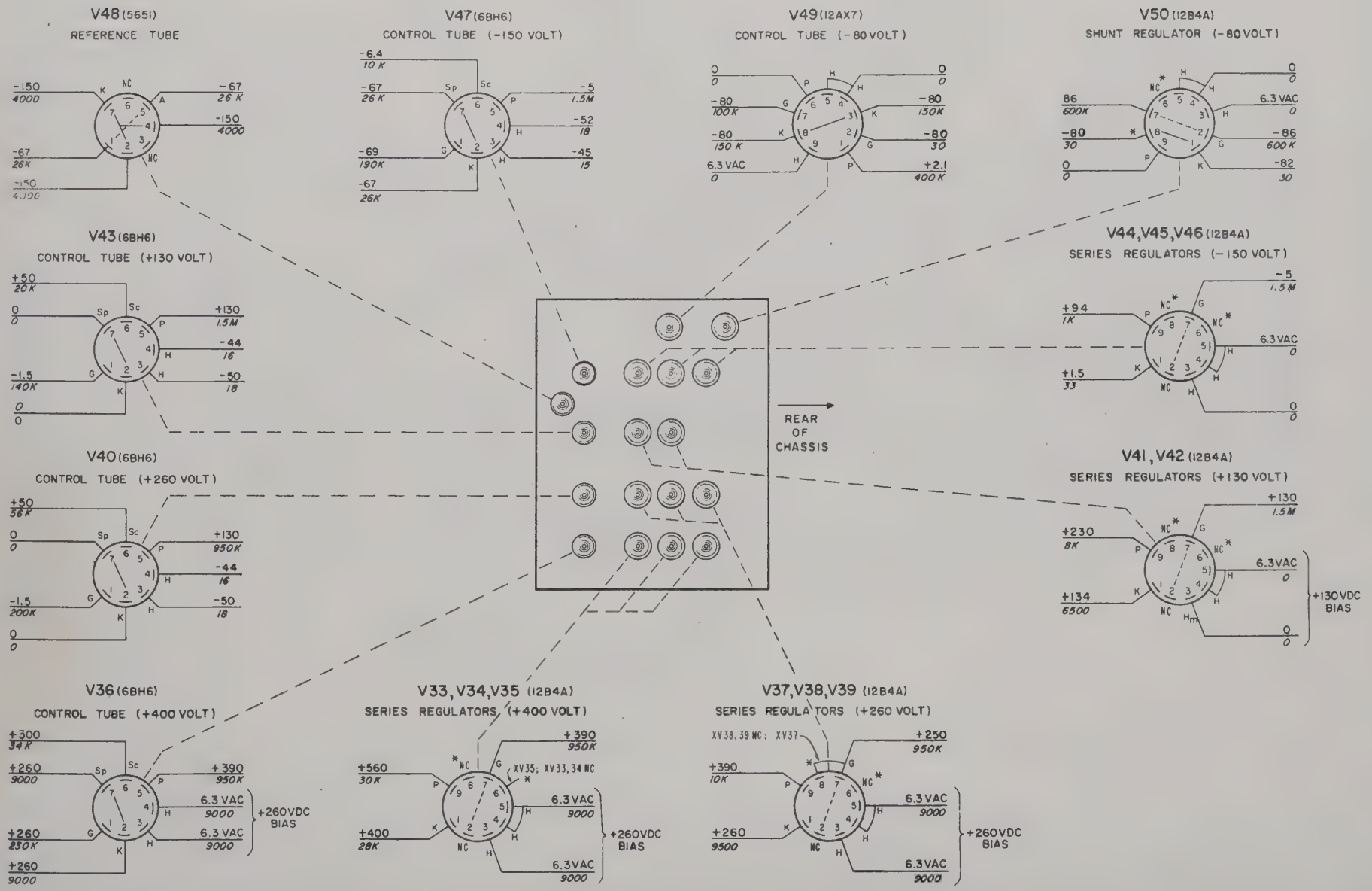
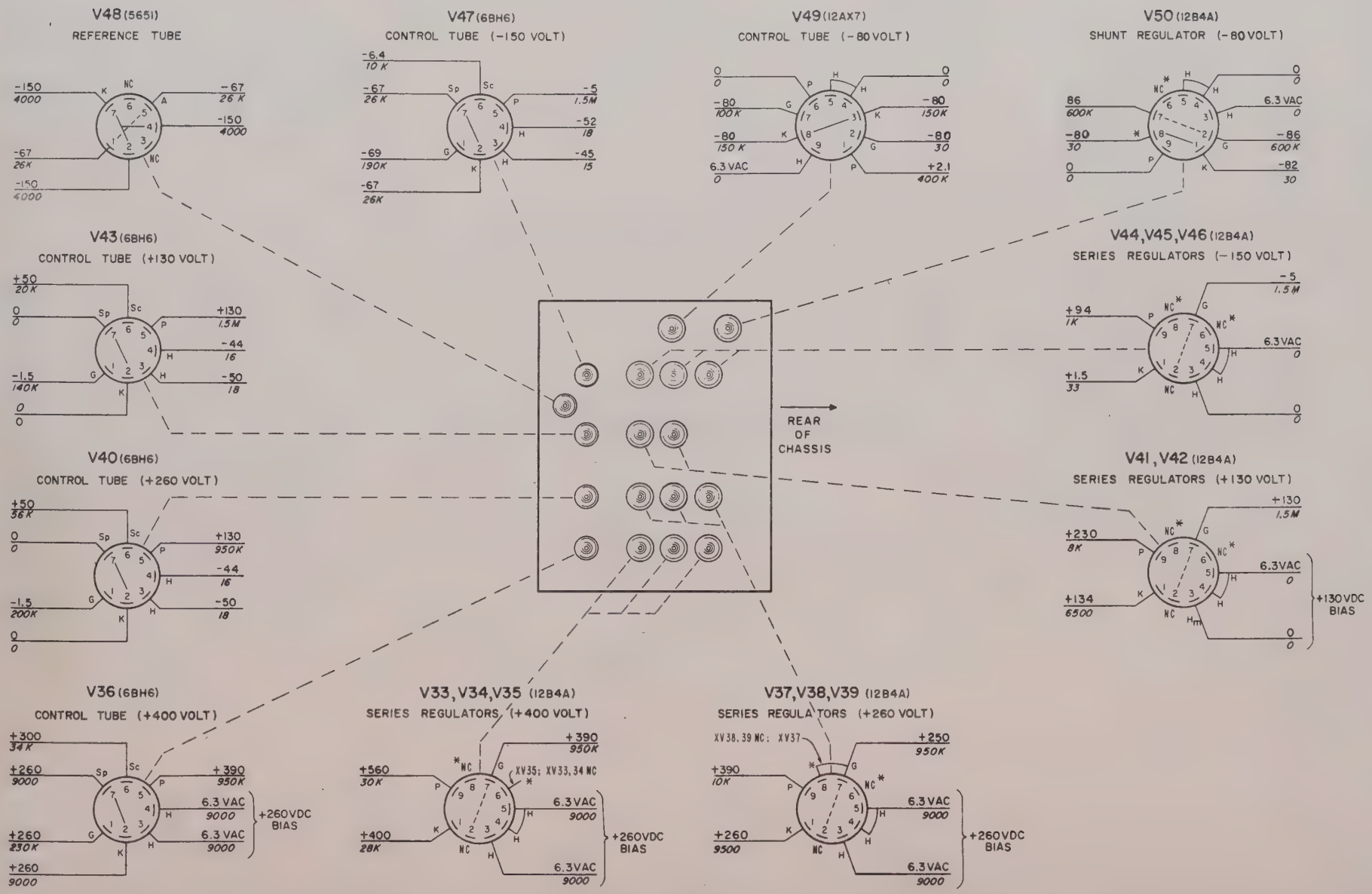


FIGURE 4-15
LOW VOLTAGE POWER SUPPLY

LOW VOLTAGE POWER SUPPLY

VOLTAGE – RESISTANCE DIAGRAM (VIEWED FROM OUTSIDE)



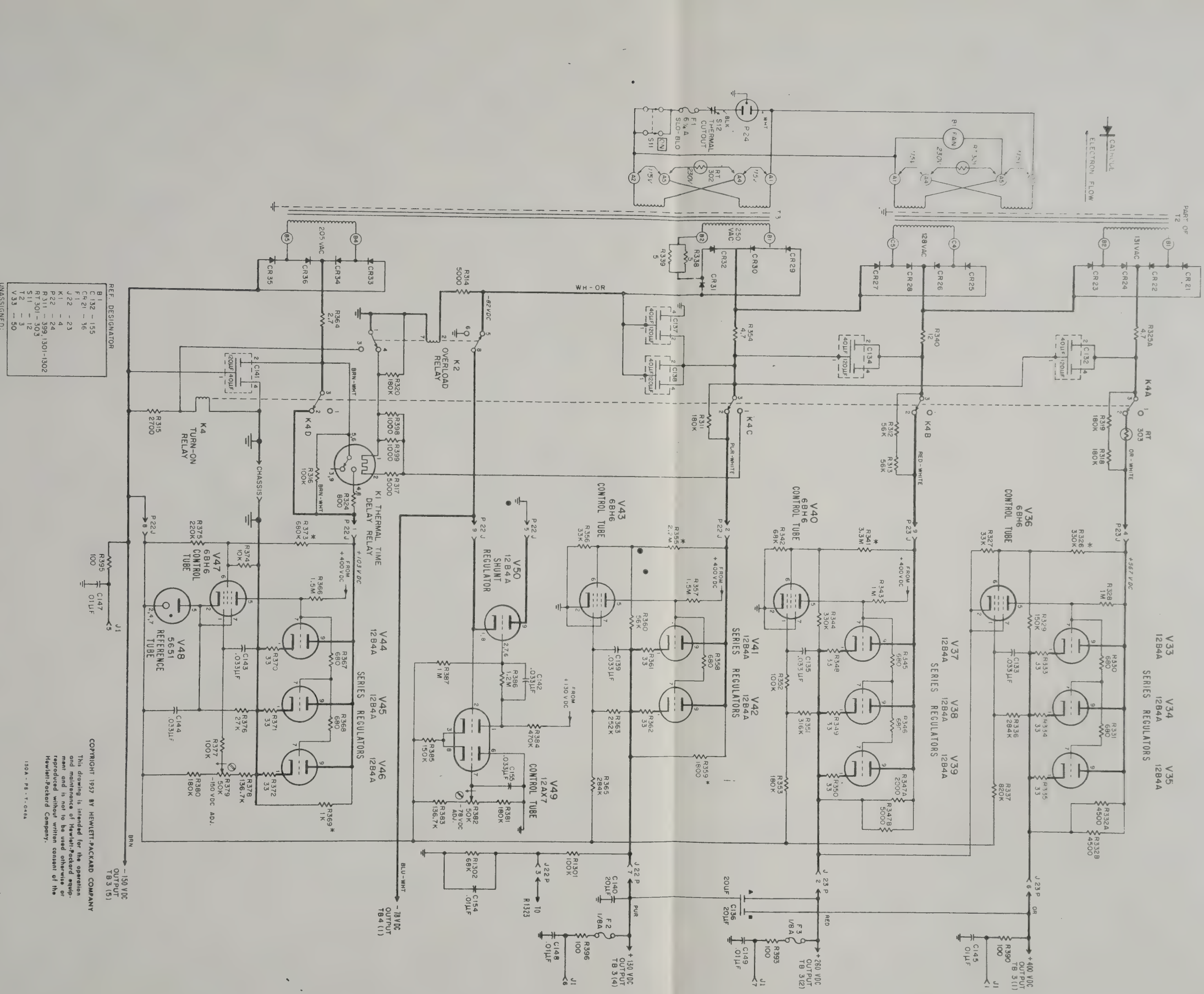
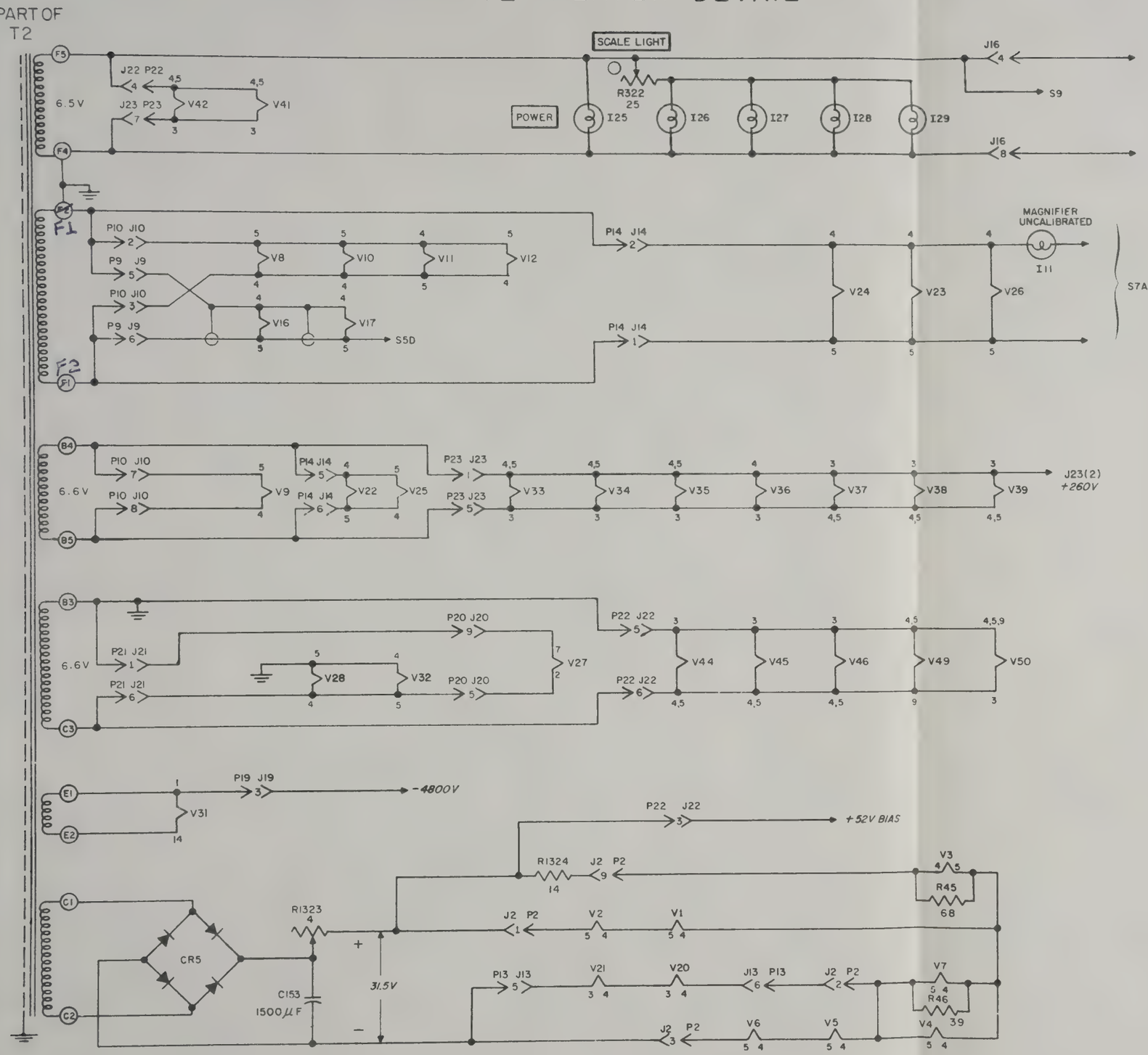


FIGURE 4-15
LOW VOLTAGE POWER SUPPLY

FIGURE 4-16
T2 FILAMENT DETAIL
AND CONNECTORS

T2 HEATER DETAIL



REGULATED DC HEATER DETAIL

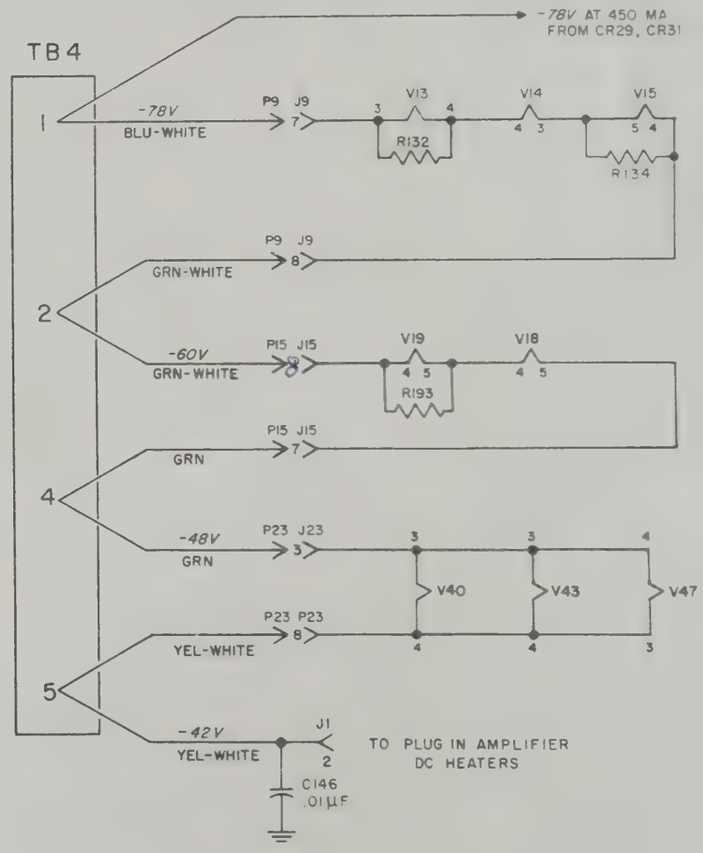


FIGURE 4-16
T2 FILAMENT DETAIL AND CONNECTORS

SECTION V
REPLACEABLE PARTS

NOTE

Standard components have been used in this instrument, whenever possible. Special components may be obtained from your local Hewlett-Packard representative or from the factory.

When ordering parts always include:

1. ℗ Stock Number.
2. Complete description of part including circuit reference.
3. Model number and serial number of instrument.
4. If part is not listed, give complete description, function and location of part.

Corrections to the Table of Replaceable Parts are listed on an Instruction Manual Change sheet at the front of this manual.

RECOMMENDED SPARE PARTS LIST

Column RS in the Table lists the recommended spare parts quantities to maintain one instrument for one year of isolated service. Order complete spare parts kits from the Factory Parts Sales Department. ALWAYS MENTION THE MODEL AND SERIAL NUMBERS OF INSTRUMENTS INVOLVED.

TABLE OF REPLACEABLE PARTS

Circuit Ref.	Description	Mfr. *	Stock No.	TQ	RS		
B1	Fan, motor	83821	3140-0006	1	1		
	Blade, fan	06812	3160-0009	1	1		
C1	Capacitor: selected values, set of four, includes C3, 5, and 6	28480	150A-95D	1	1		
C2	Not assigned						
C3	Part of C1						
C4	Not assigned						
C5, 6	Part of C1						
C7	Capacitor: fixed, ceramic disc, .02 μf ±10%, 600 vdcw	91418	0150-0024	6	2		
C8	Capacitor: variable, ceramic, trimmer 5-25 pf NPO temp. coeff	72982	0130-0012	4	1		
C9	Capacitor: fixed, mica, 47 pf ±5%, 300 vdcw	76433	0140-0039	2	1		
C10	Capacitor: fixed, titanium dioxide, 3.9 pf ±10%, 500 vdcw	78488	0150-0034	1	1		
C11	Capacitor: fixed, mylar, 0.1 μf ±5%, 200 vdcw	84411	0170-0019	2	1		
C12, 13	Same as C7						
C14	Not assigned						
C15	Capacitor: variable, mica, 110-580 pf, 175 vdcw	72136	0131-0002	1	1		
C16 thru C19	Not assigned						
C20	Capacitor: fixed, paper, 0.1 μf ±10%, 400 vdcw	56289	0160-0013	1	1		
C21	Capacitor: fixed, mica, 820 pf ±10%, 500 vdcw	76433	0140-0010	3	1		
C22	Capacitor: fixed, mylar, .01 μf ±5%, 400 vdcw	84411	0170-0017	2	1		
C23	Same as C21						
C24	Capacitor: fixed, ceramic, .01 μf ±20%, 1000 vdcw	56289	0150-0012	11	3		

* Refer to "List of Manufacturers' Codes".
TQ Total Quantity used in the instrument.
RS Recommended spares for one year isolated service for one instrument.

TABLE OF REPLACEABLE PARTS

Circuit Ref.	Description	Mfr. *	℗ Stock No.	TQ	RS		
C25	Capacitor: fixed, mica, 39 pf ±5%, 300 vdcw	76433	0140-0035	2	1		
C26	Capacitor: fixed, paper, .022 μf ±10%, 600 vdcw	56289	0160-0003	1	1		
C27	Capacitor: fixed, paper, .01 μf ±5%, 600 vdcw	56289	0160-0019	5	2		
C28 thru C30	Capacitor: fixed, mica, 10 pf ±10%, 500 vdcw	76433	0140-0002	4	1		
C31	Capacitor: fixed, silver mica, 820 pf ±5%, 500 vdcw	76433	0140-0091	1	1		
C32	Capacitor: fixed, mica, 100 pf ±5%, 500 vdcw	76433	0140-0041	3	1		
C33	Same as C24						
C34	Capacitor: fixed, mica, 68 pf ±10%, 500 vdcw	00853	0140-0025	1	1		
C35	Same as C9						
C36	Capacitor: fixed, mica, .01 μf ±10%, 300 vdcw	76433	0140-0008	3	1		
C37	Same as C27						
C38	Capacitor: fixed, titanium dioxide 6.8 pf ±10%, 500 vdcw	78488	0150-0047	1	1		
C39	Same as C27						
C40	Capacitor: variable, ceramic, trimmer 3-12 pf NPO temp. coeff	72982	0130-0013	2	1		
C41	Capacitor: fixed, mica, 150 pf ±10%, 500 vdcw (rack mount only)	76433	0140-0055	1	1		
C42	Same as C32 (rack mount only)						
C43	Same as C24						
C44	Capacitor: fixed, titanium dioxide, 2.2 pf ±10%, 500 vdcw	78488	0150-0015	1	1		
C45	Not assigned						
C46, 47	Same as C24						
C48	Capacitor: fixed, ceramic, 10 pf ±0.5 pf, 500 vdcw	04222	0150-0009	1	1		

* Refer to "List of Manufacturers' Codes".
TQ Total Quantity used in the instrument.
RS Recommended spares for one year isolated service for one instrument.

TABLE OF REPLACEABLE PARTS

Circuit Ref.	Description	Mfr. *	hp Stock No.	TQ	RS		
C49	Same as C32						
C50	Capacitor: fixed, paper, .01 μf ±20%, 400 vdcw	56289	0160-0054	1	1		
C51	Capacitor: fixed, paper, .47 μf ±10%, 200 vdcw	56289	0160-0015	1	1		
C52	Capacitor: fixed, paper, .051 μf ±10%, 200 vdcw	00853	0170-0003	2	1		
C53	Capacitor: fixed, mica, 4700 pf ±10%, 500 vdcw	76433	0140-0017	1	1		
C54	Capacitor: fixed, mica, 470 pf ±10%, 500 vdcw	76433	0140-0027	2	1		
C55	Capacitor: fixed, mylar, 1 μf ±5%, 200 vdcw	84411	0170-0018	1	1		
C56	Same as C11						
C57	Same as C22						
C58	Capacitor: fixed, silver mica, .001 μf ±5%, 500 vdcw	00656	0140-0079	1	1		
C59	Capacitor: variable, ceramic, 7-45 pf, 500 vdcw	72982	0130-0001	3	1		
C60	Capacitor: fixed, ceramic, 82 pf ±5%, 500 vdcw	04222	0150-0004	2	1		
C61	Capacitor: variable, ceramic, 8-50 pf, N750 temp. coeff	72982	0130-0008	3	1		
C62	Same as C60						
C63	Same as C25						
C64	Same as C8						
C65	Same as C40						
C66	Capacitor: fixed, ceramic, 5 pf ±0.5 pf, 500 vdcw, NPO temp. coeff.	72982	0150-0008	1	1		
C67	Capacitor: variable, trimmer, ceramic, 1.5-7 pf, NPO temp. coeff	72982	0130-0011	3	1		
C68, 69	Not assigned						

* Refer to "List of Manufacturers' Codes".
TQ Total Quantity used in the instrument.
RS Recommended spares for one year isolated service for one instrument.

TABLE OF REPLACEABLE PARTS

Circuit Ref.	Description	Mfr. *	℗ Stock No.	TQ	RS		
C70	Capacitor: fixed, mica, 27 pf ±5%, 300 vdcw	76433	0140-0042	1	1		
C71, 72	Same as C67						
C73, 74	Capacitor: fixed, mica, 47 pf ±10%, 500 vdcw	76433	0140-0032	2	1		
C75	Same as C8						
C76	Not assigned						
C77, 78	Same as C61						
C79	Capacitor: fixed, mica, 82 pf ±10%, 500 vdcw	76433	0140-0006	1	1		
C80	Capacitor: fixed, titanium dioxide, 3.3 pf ±10%, NPO temp. coeff	78488	0150-0022	1	1		
C81	Same as C21						
C82	Same as C8						
C83	Capacitor: fixed, titanium dioxide, 1.0 pf ±10%, 500 vdcw	78488	0150-0029	1	1		
C84	Same as C59						
C85	Capacitor: variable, clip, 0-.5 pf	28480	150A-7A	2	1		
C86	Capacitor: variable, ceramic, 5-20 pf, 500 vdcw	72982	0130-0006	1	1		
C87	Capacitor: fixed, mica, 200 pf ±10%, 500 vdcw	76433	0140-0056	1	1		
C88	Same as C59						
C89	Same as C85						
C90, 91	Same as C36						
C92 thru C94	Capacitor: fixed, paper, .02 μf ±5%, 600 vdcw	56289	0160-0020	3	1		
C95, 96	Capacitor: fixed, titanium dioxide, 8.2 pf ±10%, 500 vdcw	76488	0150-0033	2	1		
C97	Not assigned						

* Refer to "List of Manufacturers' Codes".
TQ Total Quantity used in the instrument.
RS Recommended spares for one year isolated service for one instrument.

TABLE OF REPLACEABLE PARTS

Circuit Ref.	Description	Mfr. *	Stock No.	TQ	RS		
C98	Capacitor: fixed, mica, 27 pf ±10%, 500 vdcw	76433	0140-0005	1	1		
C99, 100	Not assigned						
C101	Capacitor: fixed, paper, .0022 μf ±10%, 600 vdcw	76289	0160-0007	1	1		
C102	Capacitor: fixed, paper, 0.1 μf ±10%, 600 vdcw	56289	0160-0001	1	1		
C103	Not assigned						
C104	Same as C54						
C105	Same as C52						
C106	Capacitor: fixed, mica, 56 pf ±10%, 500 vdcw	76433	0140-0014	1	1		
C107	Same as C28						
C108	Capacitor: fixed, paper, 1 μf ±10%, 600 vdcw	00853	0160-0079	1	1		
C109, 110	Capacitor: fixed, paper, .0015 μf, 6000 vdcw	56289	0160-0063	2	1		
C111	Capacitor: fixed, paper, .0047 μf ±20%, 6000 vdcw	56289	0160-0036	7	2		
C112	Capacitor: fixed, ceramic, 470 pf ±20%, 6000 vdcw	91418	0150-0036	1	1		
C113,114	Same as C111						
C115	Same as C24						
C116,117	Capacitor: fixed, silver mica, 200 pf ±5%, 500 vdcw	56289	0140-0090	2	1		
C118	Same as C27						
C119	Capacitor: fixed, mica, 15 pf ±10%, 500 vdcw	76433	0140-0004	1	1		
C120 thru C123	Same as C111						
C124 thru C131	Not assigned						

* Refer to "List of Manufacturers' Codes".
TQ Total Quantity used in the instrument.
RS Recommended spares for one year isolated service for one instrument.

TABLE OF REPLACEABLE PARTS

Circuit Ref.	Description	Mfr. *	Stock No.	TQ	RS		
C132	Capacitor: fixed, electrolytic, 2 sections, 120 x 40 μf, 400 vdcw	56289	0180-0030	5	2		
C133	Capacitor: fixed, paper, .033 μf ±10%, 400 vdcw	00656	0170-0018	7	2		
C134	Same as C132						
C135	Same as C133						
C136	Capacitor: fixed, electrolytic, 4 sections, 20 μf/sect., 450 vdcw	56289	0180-0025	2	1		
C137,138	Same as C132						
C139	Same as C133						
C140	Same as C136						
C141	Same as C132						
C142 thru C144	Same as C133						
C145 thru C149	Same as C24						
C150 thru C152	Same as C7						
C153	Capacitor: fixed, electrolytic, 1500 μf, 50 vdcw	56289	0180-0040	1	1		
C154	Same as C27						
C155	Same as C133						
CR1	Diode, crystal: type 1N55	93332	1910-0003	1	1		
CR2	Diode, crystal	28480	G-29A-50	1	1		
CR3	Diode, crystal: type HD2135	73293	1910-0011	3	3		
CR4	Diode, crystal: type 1N38A	93332	1910-0002	1	1		
CR5	Not assigned						
CR6, 7	Same as CR3						
CR8 thru CR10	Breakdown diodes: selected set	28480	G-172A	1	1		

* Refer to "List of Manufacturers' Codes".
TQ Total Quantity used in the instrument.
RS Recommended spares for one year isolated service for one instrument.

TABLE OF REPLACEABLE PARTS

Circuit Ref.	Description	Mfr. *	Stock No.	TQ	RS		
CR11 thru CR18	Breakdown diodes: selected set	28480	G-172B	1	1		
CR19,20	Not assigned						
CR21 thru CR28	Rectifier, silicon: 400 volts, PIV	84970	1901-0007	12	12		
CR29 thru CR32	Rectifier, silicon: 500 volts, PIV	84970	1901-0009	4	4		
CR33 thru CR36	Same as CR21						
DL1A,1B	Delay lines: matched pair, 2200 ohms	28480	150A-16AF	1	1		
F1	Fuse, cartridge: 6.25 amp, slow blow, 250 volts (115 volt operation)	71400	2110-0023	1	10		
	Fuse, cartridge: 3.2 amp, slow blow (230 volt operation)	71400	2110-0013				
F2, 3	Fuse, cartridge: 1/8 amp, fast blow, 250 volts (do not use slow blow)	75915	2110-0027	2	20		
I1, 2	Neon, lamp: type NE-2	24455	2140-0008	2	2		
I3, 4	Neon, selected: blue coding	28480	G-84B	5	5		
I5	Neon, selected: green coding	28480	G-84D	2	2		
I6	Lamp, neon: glow, 1/25 W, NE51	24455	2140-0006	1	1		
I7 thru I10	Not assigned						
I11, 12	Lamp, incandescent: 6 volts, type 51	24455	2140-0010	2	2		
I13 thru I15	Same as I3						
I16 thru I24	Not assigned						

* Refer to "List of Manufacturers' Codes".
TQ Total Quantity used in the instrument.
RS Recommended spares for one year isolated service for one instrument.

TABLE OF REPLACEABLE PARTS

Circuit Ref.	Description	Mfr. *	hp Stock No.	TQ	RS		
I25 thru I29	Lamp, incandescent: 6-8 volts, .15 amp, #47	24455	2140-0009	5	5		
J1	Connector, female: 8 contact	02660	1251-0009	2	1		
J2	Socket, tube: 9 pin	71785	1200-0008	1	1		
J3	Binding post: red	28480	AC-10D	3	1		
	Binding post: black	28480	AC-10C	2	1		
	Insulator	28480	AC-54A	2	0		
J4	Connector: BNC	91737	1250-0001	2	1		
J5, 6, 7	Connector: BNC	91737	1250-0083	3	1		
J8, 9, 10	Socket, tube: 9 pin, miniature type	28480	G-76D	11	3		
J11	Same as J4						
J12	Same as J3						
J13 thru J15	Same as J8						
J16	Same as J1						
J17	Same as J3						
J18	Binding post: red	28480	AC-10D		0		
	Binding post: insulator, single, black	28480	AC-54D	4	0		
J19 thru J23	Same as J8						
K1	Relay, time delay: 9 pin miniature	94197	0490-0012	1	1		
K2	Relay, DPDT: coil, 115 vdc	77342	0490-0016	1	1		
K3	Not assigned						
K4	Relay, armature: 4PDT, coil, 110 vdc	77342	0490-0014	1	1		
L1, 2	Bridged "T" Coil Assembly	28480	150A-60J	2	1		
L3, 4	Coil, R.F.: 9 μh	28480	150A-60D	2	1		
L5, 6, 7	Not assigned						
L8	Coil, choke: 10 μh ±10%	99848	9140-0032	1	1		

* Refer to "List of Manufacturers' Codes".
TQ Total Quantity used in the instrument.
RS Recommended spares for one year isolated service for one instrument.

TABLE OF REPLACEABLE PARTS

Circuit Ref.	Description	Mfr.*	Stock No.	TQ	RS		
L9	Not assigned						
L10, 11	Coil, R.F.: 35 μh ±10%	99848	9140-0027	4	1		
L12	Coil, R.F.: 100 μh	28480	150A-60K	1	1		
L13	Coil, R.F.: 240 μh	28480	150A-60L	1	1		
L14	Coil, R.F.: 20 mh	28480	150A-60E	1	1		
L15, 16	Coil, R.F. 5.5 mh	28480	150A-60M	2	1		
L17, 18	Same as L10						
L19 thru L29	Not assigned						
L30	Coil, R.F.: 200 μh	99848	9140-0019	1	1		
L31	Coil, R.F.: 16 mh	99848	9140-0004	1	1		
P1	Not assigned						
P2	Plug, male: 9 pin miniature, short	28480	150A-95F	1	1		
P3 thru P7	Not assigned						
P8, 9, 10	Plug, male: 9 pin miniature, long	28480	150A-95E	10	1		
P11, 12	Not assigned						
P13, 14, 15	Same as P8						
P16, 17, 18	Not assigned						
P19	Plug, Assembly, male: 9 pin miniature, long	28480	150A-95T	1	1		
P20, 21 22, 23	Same as P8						
P24	Power cord	70903	8120-0015	1	1		
R1	Resistor: fixed, metal film, 2200 ohms, ±1%, 4 W	07115	0769-0001	2	1		
R2, 3	Resistor: fixed, composition, 47 ohms, ±10%, 1/2 W	01121	0687-4701	9	2		

* Refer to "List of Manufacturers' Codes".
TQ Total Quantity used in the instrument.
RS Recommended spares for one year isolated service for one instrument.

TABLE OF REPLACEABLE PARTS

Circuit Ref.	Description	Mfr.*	Stock No.	TQ	RS		
R4	Resistor: fixed, deposited carbon, 180,000 ohms, ±1%, 1/2 W	19701	0727-0050	7	2		
R5	Resistor: variable 100 ohms, ±20%, 0.2 W	71450	2100-0118	1	1		
R6, 7	Resistor: fixed, metal film, 5000 ohms, ±5%, 5 W	07115	0773-0002	2	1		
R8	Same as R1						
R9, 10, 11	Same as R4						
R12, 13	Resistor: fixed, carbon film 2200 ohms, ±1%, 1/4 W	19701	0724-0021	2	1		
R14	Resistor: fixed, wirewound, 1000 ohms, ±10%, 10 W	35434	0816-0011	1	1		
R15	Same as R2						
R16, 17	Resistor: fixed, composition, 6800 ohms ±10%, 1 W	01121	0690-6821	4	1		
R18	Same as R2						
R19, 20	Same as R16						
R21, 22	Same as R2						
R23	Resistor: fixed, composition, 470 ohms, ±5%, 1/2 W	01121	0686-4715	4	1		
R24	Resistor: fixed, metal film, 1750 ohms, ±5%, 7 W	07115	0776-0002	2	1		
R25	Resistor: fixed, metal film 2000 ohms, ±5%, 7 W	07115	0776-0003	2	1		
R26	Same as R23						
R27, 28, 29	Resistor: fixed, metal film, 400 ohms, ±5%, 3 W	07115	0767-0001	3	1		
R30, 31	Same as R23						
R32	Same as R25						
R33	Same as R24						
R34	Resistor: fixed, composition, 10 megohms ±10%, 1/2 W	01121	0687-1061	1	1		

* Refer to "List of Manufacturers' Codes".
TQ Total Quantity used in the instrument.
RS Recommended spares for one year isolated service for one instrument.

TABLE OF REPLACEABLE PARTS

Circuit Ref.	Description	Mfr.*	Stock No.	TQ	RS		
R35	Resistor: fixed, composition, 3.3 megohms ±10%, 1/2 W	01121	0687-3351	2	1		
R36	Same as R2						
R37	Resistor: fixed, composition, 2200 ohms ±10%, 1 W	01121	0690-2221	3	1		
R38	Resistor: fixed, composition, 91 ohms ±5%, 1/2 W	01121	0686-9105	1	1		
R39	Same as R2						
R40	Resistor: fixed, metal film, 6500 ohms ±5%, 3 W	07115	0767-0006	2	1		
R41	Same as R2						
R42A, B	Resistor: variable, potentiometer, 10,000 ohms/sect. ±20% each section	71450	2100-0150	1	1		
R43	Resistor: fixed, composition, 22 ohms ±10%, 1/2 W	01121	0687-2201	2	1		
R44	Not assigned						
R45	Resistor: fixed, composition, 68 ohms ±10%, 2 W	01121	0693-6801	3	1		
R46	Resistor: fixed, composition, 39 ohms ±5%, 2 W	01121	0692-3905	2	1		
R47 thru R50	Not assigned						
R51, 52	Resistor: fixed, composition, 680,000 ohms, ±10%, 1/2 W	01121	0687-6841	5	2		
R53	Resistor: fixed, composition, 270,000 ohms, ±10%, 1/2 W	01121	0687-2741	3	1		
R54	Resistor: fixed, composition, 220,000 ohms ±10%, 1/2 W	01121	0687-2241	2	1		
R55	Resistor: fixed, composition, 1 megohm ±10%, 1/2 W	01121	0687-1051	8	2		
R56	Resistor: fixed, composition, 2.2 megohms ±10%, 1/2 W	01121	0687-2251	3	1		
R57	Part of S2 (not separately replaceable)						

* Refer to "List of Manufacturers' Codes".
TQ Total Quantity used in the instrument.
RS Recommended spares for one year isolated service for one instrument.

TABLE OF REPLACEABLE PARTS

Circuit Ref.	Description	Mfr.*	Stock No.	TQ	RS		
R58	Resistor: fixed, composition, 47,000 ohms ±10%, 1/2 W	01121	0687-4731	2	1		
R59	Resistor: fixed, composition, 470,000 ohms ±10%, 1/2 W	01121	0687-4741	4	1		
R60	Resistor: fixed, composition, 56 ohms ±10%, 1/2 W	01121	0687-5601	31	6		
R61, 62	Same as R37						
R63	Resistor: fixed, metal film 24,000 ohms ±10%, 4 W	07115	0771-0005	1	1		
R64, 65	Same as R60						
R66	Resistor: variable, composition, linear taper, 2000 ohms ±30%, 1/3 W	71450	2100-0090	2	1		
R67	Resistor: fixed, composition 100 ohms ±10%, 1/2 W	01121	0687-1011	4	1		
R68	Not assigned						
R69	Resistor: fixed, metal film, 10,000 ohms ±5%, 3W	07115	0767-0008	1	1		
R70	Resistor: fixed, deposited carbon, 200,000 ohms ±1%, 1/2 W	19701	0727-0221	1	1		
R71	Resistor: fixed, deposited carbon, 526,000 ohms ±1%, 1 W	19701	0730-0094	1	1		
R72	Resistor: variable, composition, 100,000 ohms ±30%, 1/4 W	71450	2100,0095	2	1		
R73	Not assigned						
R74	Same as R60						
R75	Same as R40						
R76	Resistor: fixed, metal film, 10,000 ohms ±5%, 4 W	07115	0770-0004	1	1		
R77	Same as R67						
R78	Same as R60						
R79, 80	Resistor: fixed, deposited carbon, 37,000 ohms ±1%, 1 W	19701	0730-0049	3	1		
R81	Same as R60						

* Refer to "List of Manufacturers' Codes".
TQ Total Quantity used in the instrument.
RS Recommended spares for one year isolated service for one instrument.

TABLE OF REPLACEABLE PARTS

Circuit Ref.	Description	Mfr. *	hp Stock No.	TQ	RS		
R82	Resistor: fixed, composition, 1000 ohms ±10%, 1/2 W	01121	0687-1021	4	1		
R83	Same as R79						
R84	Resistor: fixed, composition, 56,000 ohms ±10%, 1 W	01121	0690-5631	1	1		
R85	Resistor: fixed, composition, 560,000 ohms ±10%, 1/2 W	01121	0687-5641	2	1		
R86	Resistor: fixed, composition, 180,000 ohms ±10%, 1/2 W	01121	0687-1841	2	1		
R87	Same as R60						
R88	Resistor: variable, composition, linear taper, 5000 ohms ±30%, 1/3 W	71450	2100-0091	1	1		
R89	Resistor: fixed, composition, 47,000 ohms ±10%, 2 W	01121	0693-4731	3	1		
R90	Same as R60						
R91	Resistor: fixed, metal film, 15,000 ohms ±5%, 4 W	07115	0770-0006	3	1		
R92	Same as R86						
R93	Same as R60						
R94	Resistor: fixed, composition, 5600 ohms ±10%, 1/2 W	01121	0687-5621	1	1		
R95	Resistor: fixed, metal film, 75,000 ohms ±10%, 7 W	07115	0777-0002	1	1		
R96	Resistor: fixed, composition, 22,000 ohms ±10%, 1/2 W	01121	0687-2231	2	1		
R97	Same as R60						
R98	Resistor: fixed, composition, 330,000 ohms ±10%, 1/2 W	01121	0687-3341	7	2		
R99	Not assigned						
R100	Part of S1 (not separately replaceable)						

* Refer to "List of Manufacturers' Codes".
TQ Total Quantity used in the instrument.
RS Recommended spares for one year isolated service for one instrument.

TABLE OF REPLACEABLE PARTS

Circuit Ref.	Description	Mfr. *	℔ Stock No.	TQ	RS
R101	Not assigned				
R102	Resistor: fixed, composition, 39,000 ohms ±10%, 1/2 W	01121	0687-3931	2	1
R103	Same as R72				
R104	Resistor: fixed, composition, 150,000 ohms ±10%, 1/2 W	01121	0687-1541	5	2
R105	Resistor: fixed, composition, 33,000 ohms ±10%, 1/2 W	01121	0687-3331	3	1
R106	Same as R53				
R107	Resistor: fixed, composition, 27,000 ohms ±10%, 2 W	01121	0693-2731	4	1
R108	Same as R60				
R109	Same as R107				
R110	Resistor: fixed, deposited carbon, 166,000 ohms ±1%, 1 W	19701	0730-0076	2	1
R111	Same as R60				
R112	Resistor: fixed, deposited carbon, 90,000 ohms ±1%, 1/2 W	19701	0727-0203	1	1
R113,114	Resistor: fixed, composition, 4.7 megohms ±10%, 1/2 W	01121	0687-4751	3	1
R115	Same as R60				
R116	Resistor: fixed, composition, 390,000 ohms ±10%, 1/2 W	01121	0687-3941	3	1
R117	Same as R98				
R118	Resistor: fixed, composition, 18,000 ohms ±10%, 1/2 W	01121	0687-1831	1	1
R119	Same as R107				
R120	Same as R60				
R121	Resistor: fixed, metal film, 20,000 ohms ±5%, 3 W	07115	0767-0011	3	1

* Refer to "List of Manufacturers' Codes".
TQ Total Quantity used in the instrument.
RS Recommended spares for one year isolated service for one instrument.

TABLE OF REPLACEABLE PARTS

Circuit Ref.	Description	Mfr. *	hp Stock No.	TQ	RS		
R122	Not assigned						
R123	Same as R91						
R124	Same as R59						
R125	Resistor: fixed, composition, 1.2 megohms ±10%, 1/2 W	01121	0687-1251	2	1		
R126	Resistor: fixed, composition, 820,000 ohms ±10%, 1/2 W	01121	0687-8241	1	1		
R127	Same as R60						
R128	Same as R89						
R129	Same as R98						
R130,131	Same as R60						
R132	Same as R46						
R133	Resistor: fixed, composition, 1200 ohms ±10%, 1/2 W	01121	0687-1221	1	1		
R134	Same as R45						
R135	Resistor: variable, composition, linear taper, 10,000 ohms ±20%, 1/4 W	71450	2100-0092	1	1		
R136	Same as R55						
R137 thru R139	Not assigned						
R140	Same as R104						
R141	Same as R59						
R142	Same as R104						
R143 thru R145	Resistor: variable, 20,000 ohms 1/4 W	71450	2100-0093	4	1		
R146	Resistor: variable, composition, linear taper, 50,000 ohms ±30%, 1/2 W (includes S6)	71450	2100-0107	1	1		
R147	Resistor: fixed, composition, 15,000 ohms ±10%, 1/2 W	01121	0687-1531	1	1		

* Refer to "List of Manufacturers' Codes".
TQ Total Quantity used in the instrument.
RS Recommended spares for one year isolated service for one instrument.

TABLE OF REPLACEABLE PARTS

Circuit Ref.	Description	Mfr.*	(hp) Stock No.	TQ	RS		
R148	Resistor: fixed, deposited carbon, 36 megohms ±1%, 2 W	04222	0733-0009	1	1		
R149,150	Resistor: fixed, deposited carbon, 12 megohms ±1%, 1 W	19701	0730-0145	2	1		
R151	Resistor: fixed, deposited carbon, 3.6 megohms ±1%, 1/2 W	19701	0727-0294	1	1		
R152,153	Resistor: fixed, deposited carbon, 1.2 megohms ±1%, 1/2 W	19701	0727-0280	2	1		
R154	Resistor: fixed, deposited carbon, 360,000 ohms ±1%, 1/2 W	19701	0727-0235	1	1		
R155,156	Resistor: fixed, deposited carbon, 120,000 ohms ±1%, 1/2 W	19701	0727-0214	3	1		
R157	Same as R143						
R158,159	Resistor: fixed, composition, 56,000 ohms ±10%, 1/2 W	01121	0687-5631	5	2		
R160	Same as R155						
R161	Same as R67						
R162	Resistor: fixed, composition, 10 ohms ±10%, 1/2 W	01121	0687-1001	1	1		
R163 thru R168	Not assigned						
R169	Same as R96						
R170	Same as R102						
R171	Resistor: fixed, deposited carbon, 900,000 ohms ±1%, 1/2 W	19701	0727-0259	1	1		
R172	Resistor: fixed, deposited carbon, 111,000 ohms ±1%, 1/2 W	19701	0727-0210	1	1		
R173	Resistor: fixed, deposited carbon, 1 megohm ±1%, 1/2 W	19701	0727-0274	1	1		
R174	Same as R60						
R175	Resistor: fixed, deposited carbon, 4900 ohms ±1%, 1 W	19701	0730-0021	1	1		

* Refer to "List of Manufacturers' Codes".
TQ Total Quantity used in the instrument.
RS Recommended spares for one year isolated service for one instrument.

TABLE OF REPLACEABLE PARTS

Circuit Ref.	Description	Mfr.*	Stock No.	TQ	RS		
R176	Resistor: fixed, deposited carbon, 92,600 ohms ±1%, 1/2 W	19701	0727-0205	1	1		
R177	Resistor: variable, composition, 10,000 ohms (includes S8)	71450	2100-0114	1	1		
R178	Same as R66						
R179	Same as R91						
R180	Not assigned						
R181	Resistor: fixed, deposited carbon, 33,000 ohms ±1%, 1 W	19701	0730-0048	1	1		
R182	Same as R60						
R183	Resistor: fixed, deposited carbon, 193,000 ohms ±1%, 1 W	19701	0730-0078	2	1		
R184	Same as R89						
R185	Resistor: variable, composition, linear taper, 1000 ohms ±30%, 2 W	71450	2100-0154	1	1		
R186	Resistor: variable, 50,000 ohms ±5%, 3 W	73138	2100-0121	1	1		
R187	Same as R110						
R188	Resistor: fixed, deposited carbon, 49,000 ohms ±1%, 1 W	19701	0730-0051	1	1		
R189	Resistor: variable, composition, linear taper, 500,000 ohms ±30% 1/4 W	71450	2100-0102	3	1		
R190	Same as R53						
R191	Resistor: fixed, deposited carbon, 51,600 ohms ±1%, 1 W	19701	0730-0052	1	1		
R192	Resistor: fixed, deposited carbon, 15,500 ohms ±1%, 1/2 W	19701	0727-0169	1	1		
R193	Same as R45						
R194	Same as R183						
R195	Not assigned						

* Refer to "List of Manufacturers' Codes".
TQ Total Quantity used in the instrument.
RS Recommended spares for one year isolated service for one instrument.

TABLE OF REPLACEABLE PARTS

Circuit Ref.	Description	Mfr.*	Stock No.	TQ	RS
R196	Resistor: fixed, deposited carbon, 1.39 megohms ±1%, 1/2 W	19701	0727-0281	1	1
R197	Same as R60				
R198	Resistor: fixed, deposited carbon, 160,000 ohms ±1%, 1 W	19701	0730-0075	1	1
R199	Same as R189				
R200	Resistor: fixed, metal film, 38,000 ohms ±10%, 4 W	07115	0771-0008	2	1
R201,202	Same as R51				
R203	Resistor: fixed, composition, 33,000 ohms ±10%, 2 W	01121	0693-3331	1	1
R204	Same as R60				
R205	Resistor: fixed, metal film, 11,000 ohms ±5%, 4 W	07115	0770-0005	2	1
R206	Resistor: fixed, composition, 47,000 ohms ±10%, 1 W	01121	0690-4731	2	1
R207	Resistor: variable, composition, linear taper, 5000 ohms ±20%, 1/2 W	71450	2100-0082	1	1
R208,209	Resistor: fixed, metal film, 17,500 ohms ±1%, 2 W	07115	0763-0003	2	1
R210	Same as R60				
R211	Same as R205				
R212	Same as R206				
R213	Resistor: variable, potentiometer, 500 ohms ±20%, 0.2 W	71450	2100-0151	1	1
R214	Resistor: fixed, carbon film, 11,880 ohms ±1%, 1/2 W	19701	0727-0163	1	1
R215	Resistor: fixed, carbon film, 2030 ohms ±1%, 1/2 W	19701	0727-0116	1	1
R216	Resistor: fixed, deposited carbon, 4860 ohms ±1%, 1/2 W	19701	0727-0135	1	1
R217	Resistor: fixed, deposited carbon, 490 ohms ±1%, 1/2 W	19701	0727-0075	1	1

* Refer to "List of Manufacturers' Codes".
TQ Total Quantity used in the instrument.
RS Recommended spares for one year isolated service for one instrument.

TABLE OF REPLACEABLE PARTS

Circuit Ref.	Description	Mfr. *	hp Stock No.	TQ	RS		
R218	Resistor: fixed, deposited carbon, 30,500 ohms ±1%, 1 W	19701	0730-0045	2	1		
R219	Resistor: fixed, deposited carbon, encapsulated, 80,000 ohms ±1%, 1 W	28480	150A-26A	2	1		
R220	Same as R60						
R221	Resistor: fixed, metal film, 30,000 ohms ±10%, 4 W	07115	0771-0007	2	1		
R222	Same as R60						
R223	Same as R218						
R224	Same as R219						
R225	Same as R221						
R226	Same as R60						
R227	Same as R116						
R228,229	Same as R98						
R230	Resistor: fixed, wirewound, 3000 ohms ±10%, 20 W	83777	0819-0015	1	1		
R231	Same as R116						
R232	Same as R60						
R233	Resistor: fixed, wirewound, 12,000 ohms ±10%, 20 W	83777	0819-0014	2	1		
R234	Same as R60						
R235	Same as R233						
R236	Same as R60						
R237	Resistor: fixed, composition, 470 ohms ±10%, 1/2 W	01121	0687-4711	1	1		
R238	Same as R60						
R239	Resistor: fixed, composition, 2700 ohms ±10%, 1/2 W	01121	0687-2721	2	1		
R240,241	Resistor: fixed, composition, 2200 ohms ±10%, 1/2 W	01121	0687-2221	2	1		
R242	Same as R239						

* Refer to "List of Manufacturers' Codes".
TQ Total Quantity used in the instrument.
RS Recommended spares for one year isolated service for one instrument.

TABLE OF REPLACEABLE PARTS

Circuit Ref.	Description	Mfr. *	Stock No.	TQ	RS		
R243	Same as R60						
R244,245	Resistor: fixed, composition, 100,000 ohms ±10%, 2 W	01121	0693-1041	4	1		
R246	Same as R60						
R247	Not assigned						
R248	Same as R58						
R249	Same as R107						
R250 thru R254	Not assigned						
R255	Same as R82						
R256	Resistor: fixed, metal film, 12,000 ohms ±5%, 3 W	07115	0767-0009	1	1		
R257	Resistor: variable, composition, 2500 ohms, 1/2 W	71590	2100-0067	1	1		
R258	Same as R158						
R259,260	Resistor: fixed, composition, 150 ohms ±10%, 1/2 W	01121	0687-1511	2	1		
R261	Resistor: fixed, composition, 330 ohms ±10%, 1/2 W	01121	0687-3311	1	1		
R262	Same as R82						
R263	Same as R85						
R264	Same as R158						
R265	Resistor: variable, composition, 200,000 ohms	12697	2100-0014	1	1		
R266	Resistor: fixed, deposited carbon, 50 megohms ±10%, 2 W	77764	0836-0001	2	1		
R267	Resistor: variable, composition, linear taper, 100,000 ohms	71450	2100-0063	1	1		
R268	Same as R56						
R269	Resistor: fixed, composition, 10,000 ohms ±10%, 1/2 W	01121	0687-1031	2	1		
R270	Same as R200						

* Refer to "List of Manufacturers' Codes".
TQ Total Quantity used in the instrument.
RS Recommended spares for one year isolated service for one instrument.

TABLE OF REPLACEABLE PARTS

Circuit Ref.	Description	Mfr.*	Stock No.	TQ	RS		
R271	Resistor: fixed, composition, 120,000 ohms ±10%, 1/2 W	01121	0687-1241	2	1		
R272	Resistor: fixed, composition, 100,000 ohms ±10%, 1/2 W	01121	0687-1041	5	2		
R273	Same as R244						
R274	Resistor: fixed, deposited carbon, 4.15 megohms ±1%, 1 W	19701	0730-0123	2	1		
R275	Resistor: variable, composition, 3.5 megohms ±30%, 1/4 W	71450	2100-0100	1	1		
R276	Same as R266						
R277	Resistor: variable, composition, 5 megohms ±30%, 1/2 W	12697	2100-0112	1	1		
R278	Same as R274 Optimum value selected at factory Average value shown						
R279	Resistor: fixed, composition, 27,000 ohms ±10%, 1/2 W	01121	0687-2731	1	1		
R280 thru R282	Same as R55						
R283	Resistor: variable, composition, 500,000 ohms ±20%	71590	2100-0015	1	1		
R284	Resistor: fixed, composition, 39,000 ohms ±10%, 1 W	01121	0690-3931	1	1		
R285	Resistor: fixed, composition, 6.8 megohms ±10%, 1/2 W	01121	0687-6851	1	1		
R286	Resistor: fixed, composition, 18,000 ohms ±10%, 1 W	01121	0690-1831	1	1		
R287,288	Same as R121						
R289	Resistor: fixed, deposited carbon, 7500 ohms ±1%, 1 W	19701	0730-0024	1	1		
R290	Same as R189						
R291	Resistor: fixed, deposited carbon, 5000 ohms ±1%, 1 W	19701	0730-0022	2	1		
R292	Same as R113						

* Refer to "List of Manufacturers' Codes".
TQ Total Quantity used in the instrument.
RS Recommended spares for one year isolated service for one instrument.

TABLE OF REPLACEABLE PARTS

Circuit Ref.	Description	Mfr. *	Stock No.	TQ	RS		
R293	Same as R98						
R294	Resistor: fixed, deposited carbon, 100,000 ohms ±1%, 1 W	19701	0730-0069	1	1		
R295	Resistor: fixed, deposited carbon, 100 ohms ±1%, 1/2 W	19701	0727-0043	2	1		
R296	Resistor: fixed, deposited carbon, 10,200 ohms ±1%, 1 W	19701	0730-0030	1	1		
R297	Resistor: fixed, deposited carbon, 6,490 ohms ±1%, 1/2 W	19701	0727-0143	1	1		
R298	Resistor: fixed, deposited carbon, 2,100 ohms ±1%, 1/2 W	19701	0727-0118	1	1		
R299	Resistor: fixed, deposited carbon, 1,030 ohms ±1%, 1/2 W	19701	0727-0101	1	1		
R300	Resistor: fixed, deposited carbon, 608 ohms ±1%, 1/2 W	19701	0727-0083	1	1		
R301	Resistor: fixed, deposited carbon, 201 ohms ±1%, 1/2 W	19701	0727-0055	1	1		
R302	Same as R295						
R303	Resistor: fixed, deposited carbon, 60 ohms ±1%, 1/2 W	19701	0727-0031	1	1		
R304	Resistor: fixed, deposited carbon, 40 ohms ±1%, 1/2 W	19701	0727-0018	1	1		
R305	Same as R67						
R306	Same as R82						
R307,308	Resistor: fixed, composition, 680 ohms ±10%, 1/2 W	01121	0687-6811	9	2		
R309	Same as R272						
R310	Same as R271						
R311	Resistor: fixed, composition, 180,000 ohms ±10%, 1 W	01121	0690-1841	2	1		
R312,313	Resistor: fixed, composition, 56,000 ohms ±10%, 2 W	01121	0693-5631	2	1		

* Refer to "List of Manufacturers' Codes".
TQ Total Quantity used in the instrument.
RS Recommended spares for one year isolated service for one instrument.

TABLE OF REPLACEABLE PARTS

Circuit Ref.	Description	Mfr. *	Stock No.	TQ	RS		
R314	Same as R291						
R315	Resistor: fixed, composition, 2700 ohms ±10%, 1 W	01121	0690-2721	1	1		
R316	Same as R244						
R317	Resistor: fixed, metal film, 5000 ohms ±10%, 4 W	07115	0771-0003	1	1		
R318,319	Resistor: fixed, composition, 180,000 ohms ±10%, 2 W	01121	0693-1841	2	1		
R320	Same as R311						
R321	Not assigned						
R322	Resistor: variable, wirewound, 25 ohms	01121	2100-0119	1	1		
R323	Not assigned						
R324	Resistor: fixed, wirewound, 800 ohms ±5%, 40 W	12697	0818-0008	1	1		
R325	Resistor: fixed, composition, 4.7 ohms ±10%, 1 W	01121	0699-0006	2	1		
R326	Resistor: fixed, composition, 330,000 ohms ±10%, 1 W Optimum value selected at factory Average value shown	01121	0690-3341	1	1		
R327	Same as R105						
R328	Same as R55						
R329	Same as R104						
R330,331	Same as R307						
R332A,B	Resistor: fixed, wirewound, 4500 ohms ±5%, 30 W	94310	0818-0016	2	1		
R333 thru R335	Resistor: fixed, composition, 33 ohms ±10%, 1/2 W	01121	0687-3301	11	3		
R336	Resistor: fixed, deposited carbon, 284,000 ohms ±1%, 1 W	19701	0730-0083	2	1		
R337	Resistor: fixed, deposited carbon, 820,000 ohms ±1%, 1 W	19701	0730-0101	1	1		
R338,339	Resistor: fixed, wirewound, 5 ohms ±10%, 2 W	12697	0813-0006	2	1		

* Refer to "List of Manufacturers' Codes".
TQ Total Quantity used in the instrument.
RS Recommended spares for one year isolated service for one instrument.

TABLE OF REPLACEABLE PARTS

Circuit Ref.	Description	Mfr. *	Stock No.	TQ	RS		
R340	Resistor: fixed, composition, 12 ohms ±10%, 2 W	01121	0693-1201	1	1		
R341	Same as R35 Optimum value selected at factory Average value shown						
R342	Resistor: fixed, composition, 68,000 ohms ±10%, 1/2 W	01121	0687-6831	2	1		
R343	Same as R55						
R344	Same as R98						
R345,346	Same as R307						
R347A	Resistor: fixed, wirewound, 2000 ohms ±5%, 40 W	94310	0818-0015	1	1		
R347B	Resistor: fixed, wirewound, 5000 ohms, 12 W	12697	0818-0005	1	1		
R348 thru R350	Same as R333						
R351	Resistor: fixed, deposited carbon, 316,000 ohms ±1%, 1 W	19701	0730-0085	1	1		
R352	Same as R272						
R353	Same as R4						
R354	Same as R325						
R355	Same as R56 Optimum value selected at factory Average value shown						
R356	Same as R105						
R357	Resistor: fixed, composition, 1.5 megohms ±10%, 1/2 W	01121	0687-1551	2	1		
R358	Same as R307						
R359	Resistor: fixed, wirewound, 1800 ohms ±5%, 30 W Optimum value selected at factory Average value shown	94310	0818-0017	1	1		
R360	Same as R158						

* Refer to "List of Manufacturers' Codes".
TQ Total Quantity used in the instrument.
RS Recommended spares for one year isolated service for one instrument.

TABLE OF REPLACEABLE PARTS

Circuit Ref.	Description	Mfr.*	Stock No.	TQ	RS		
R361,362	Same as R333						
R363	Resistor: fixed, deposited carbon, 252,000 ohms ±1%, 1/2 W	19701	0727-0228	1	1		
R364	Resistor: fixed, composition, 2.7 ohms ±10%, 1 W	01121	0699-0005	1	1		
R365	Same as R336						
R366	Same as R357						
R367,368	Same as R307						
R369	Resistor: fixed, wirewound, 1000 ohms ±5%, 40 W Optimum value selected at factory Average value shown	94310	0818-0014	3	1		
R370 thru R372	Same as R333						
R373	Same as R51 Optimum value selected at factory Average value shown						
R374	Same as R269						
R375	Same as R54						
R376	Resistor: fixed, composition, 27,000 ohms ±10%, 1 W	01121	0690-2731	1	1		
R377	Same as R272						
R378	Resistor: fixed, deposited carbon, 136,700 ohms ±1%, 1/2 W	19701	0727-0216	2	1		
R379	Resistor: variable, composition, linear taper, 50,000 ohms ±30%, 1/4 W	71450	2100-0094	2	1		
R380,381	Same as R4						
R382	Same as R379						
R383	Same as R378						
R384	Same as R59						
R385	Same as R104						
R386	Same as R125						

* Refer to "List of Manufacturers' Codes".
TQ Total Quantity used in the instrument.
RS Recommended spares for one year isolated service for one instrument.

TABLE OF REPLACEABLE PARTS

Circuit Ref.	Description	Mfr.*	Stock No.	TQ	RS
R387	Same as R55				
R388,389	Not assigned				
R390	Resistor: fixed, composition, 100 ohms ±10%, 1 W	75042	0699-0007	4	1
R391,392	Not assigned				
R393	Same as R390				
R394	Same as R43				
R395,396	Same as R390				
R397	Not assigned				
R398,399	Same as R369				
R400 thru R1300	Not assigned				
R1301	Same as R272				
R1302	Same as R342				
R1303 thru R1322	Not assigned				
R1323	Resistor: variable, wirewound, linear taper, 4 ohms ±10%, 4 W	71450	2100-0139	1	1
R1324	Resistor: fixed, wirewound, 14 ohms ±10%, 10 W	35434	0816-0019	1	1
RT1 thru RT300	Not assigned				
RT301, 302	Thermistor: disc type, 10 ohms ±10%, each 25°C, standard radial leads supplied on instruments wired for 230V operation only	28480	0839-0006	2	2
RT303	Thermistor: disc, 1000 ohms ±10%, at 25°C	24446	0839-0008	1	1

* Refer to "List of Manufacturers' Codes".
TQ Total Quantity used in the instrument.
RS Recommended spares for one year isolated service for one instrument.

TABLE OF REPLACEABLE PARTS

Circuit Ref.	Description	Mfr. *	Stock No.	TQ	RS		
S1	Switch, rotary: includes R100 and S3	76854	3100-0137	1	0		
	Sync Selector Switch Assembly	28480	150A-19G		1		
S2	Switch, rotary: includes R57	76854	3100-0135	1	0		
	Trigger Slope Switch Assembly	28480	150A-19B		1		
S3	Part of S1 (not separately replaceable)						
S4	Switch, toggle: DPDT	73743	3101-0005	2	1		
S5	Switch, rotary: 4 sections, 24 positions	76854	3100-0138	1	0		
	Sweep Time Switch Assembly (includes S6 and R146)	28480	150A-19JK		1		
S6	Part of R146 (not separately replaceable)						
S7	Switch, rotary: 5 sections, 11 positions	76854	3100-0145	1	0		
	Horizontal Sensitivity Switch Assembly	28480	150A-19F		1		
S8	Part of R177 (not separately replaceable)						
S9	Switch, rotary: 1 section, 19 positions	76854	3100-0142	1	0		
	Calibrator Switch Assembly	28480	150A-19E		1		
S10	Switch, toggle: SPDT	04009	3101-0002	1	1		
S11	Same as S4						
S12	Switch, thermal overload: SPST	28480	3103-0007	1	1		
T1	High Voltage Transformer	28480	150A-11C-1	1	1		
T2	Transformer, power	28480	9100-0093	1	1		
T3	Transformer, power	28480	9100-0092	1	1		
T4	Transformer, sync pulse	28480	150A-60I	1	1		
V1, 2	Tube, electron: 6CL6	82219	1923-0030	4	4		
V3, 4	Tube, electron: 6DJ8/ECC88 Tubes selected for best performance will be supplied if ordered by -hp- stock number, but tubes meeting EIA standards will normally result in the instrument operating within specifications	28480	G-73Y	13	13		
V5, 6	Tube, electron: 6197	86684	1923-0005	2	2		
V7	Tube, electron: 6AU8	33173	1933-0007	1	1		

* Refer to "List of Manufacturers' Codes".
TQ Total Quantity used in the instrument.
RS Recommended spares for one year isolated service for one instrument.

TABLE OF REPLACEABLE PARTS

Circuit Ref.	Description	Mfr. *	℗ Stock No.	TQ	RS		
V8	Tube, electron: 6DJ8/ECC88 Tubes selected for best performance will be supplied if ordered by -hp- stock number, but tubes meeting EIA standards will normally result in the instrument operating within specifications.	28480	G-73Z	1	1		
V9 thru V12	Same as V3						
V13	Tube, electron: 6AL5	33173	1930-0013	1	1		
V14	Tube, electron: 6485	94144	1923-0008	3	3		
V15 thru V17	Same as V3						
V18	Tube, electron: 6AN8	82219	1933-0001	1	1		
V19	Same as V3						
V20, 21	Same as V14						
V22	Same as V3						
V23, 24	Same as V1						
V25, 26	Same as V3						
V27	Tube, electron: 6AU5GT	33173	1923-0020	1	1		
V28	Tube, electron: 6DJ8/ECC88	73445	1932-0022	1	1		
V29, 30	Tube, electron: 1X2B	86684	1920-0004	2	2		
V31	Tube, cathode ray: 5AMP-(phosphor types available 1, 2, 7, 11, please specify)	82170	2090-0003	1	1		
V32	Tube, electron: 6U8	33173	1933-0004	1	1		
V33 thru V35	Tube, electron: 12B4A	33173	1921-0010	12	12		
V36	Tube, electron: 6BH6	33173	1923-0027	4	4		
V37 thru V39	Same as V33						
V40	Same as V36						
V41, 42	Same as V33						

* Refer to "List of Manufacturers' Codes".
TQ Total Quantity used in the instrument.
RS Recommended spares for one year isolated service for one instrument.

TABLE OF REPLACEABLE PARTS

Circuit Ref.	Description	Mfr.*	hp Stock No.	TQ	RS		
V43	Same as V36						
V44 thru V46	Same as V33						
V47	Same as V36						
V48	Tube, electron: 5651	86684	1940-0001	1	1		
V49	Tube, electron: 12AX7	00001	1932-0030	1	1		
V50	Same as V33						
Z1	Main Vertical Amplifier Assembly	28480	150A-58B	1	0		
Z2	Sweep Generator Assembly	28480	150A-65L	1	0		
Z3	Horizontal Amplifier Assembly	28480	150A-65F	1	0		
Z4	Calibrator and High Voltage Assembly	28480	150A-65K	1	0		
Z5	Low Voltage Regulator Assembly	28480	150A-65H	1	0		
Z6	High Voltage and Rectifier Assembly	28480	150A-11C	1	1		
	MISCELLANEOUS						
	Adapter: BNC to binding post	28480	AC-76A	2	1		
	Bezel Assembly: with green filter with amber filter with blue filter	28480	 160A-20G 160A-20A 160A-20B	1	0		
	Clip: for CRT neck terminals	28480	150A-76C	5	5		
	Extender, plug-in: (for servicing plug-in vertical amplifier)	28480	150A-95L	1	0		
	Fuseholder	75915	1400-0007	3	1		
	Filter, air (for cabinet model) Filter, air (for rack model)	82866 82866	3150-0007 3150-0010	1 2	1 0		
	Jewel: small lucite (for magnifier)			2	0		
	Knob: SWEEP TIME/CM, SYNC	28480	G-74Q	2	0		
	Knob: VERNIER, SWEEP MODE	28480	G-74AU	2	0		

* Refer to "List of Manufacturers' Codes".
TQ Total Quantity used in the instrument.
RS Recommended spares for one year isolated service for one instrument.

TABLE OF REPLACEABLE PARTS

Circuit Ref.	Description	Mfr. *	℗ Stock No.	TQ	RS		
	Knob: TRIGGER LEVEL	28480	G-74L	1	0		
	Knob: TRIGGER SLOPE	28480	G-74AT	1	0		
	Knob: VERNIER, HORIZONTAL POSITION	28480	G-74K	2	0		
	Knob: HORIZ. SENSITIVITY, CALIBRATOR	28480	G-74N	2	0		
	Knob: FOCUS, SCALE LIGHT, INTENSITY, ASTIGMATISM	28480	G-74D	4	0		
	Lampholder: less jewel	72765	1450-0019	1	1		
	Lever, for CRT alignment	28480	130A-49B	1	1		
	Jewel: for lampholder	72765	1450-0020	1	0		
	Probe Assembly: 10 to 1, specify 5' grey, 5' or 10' black	28480	AC-21A				
	Probe Assembly: 50 to 1, specify 5' grey, 5' or 10' black	28480	AC-21C				
	Socket, tube: 7 pin miniature, for printed circuits	71785	1200-0047	9	1		
	Socket, tube: 9 pin miniature, for printed circuits	71785	1200-0048	28	1		
	Socket: 9 pin, miniature for V29 and V30	28480	150A-11A-4	2	1		
	Socket: for V31	72825	1200-0037	1	1		
	Socket, tube: 9 pin miniature for V23 and V24	71785	1200-0031	2	1		
	Shock mount (for fan)	90179	1520-0006	4	4		
	Tube Clamp mounting ring for 9 pin etched circuit sockets	28480	G-52F	28	0		
	Tube Clamp mounting ring for 7 pin etched circuit sockets	28480	G-52E	9	0		

* Refer to "List of Manufacturers' Codes".
TQ Total Quantity used in the instrument.
RS Recommended spares for one year isolated service for one instrument.

CATHODE RAY TUBE WARRANTY

The cathode ray tube supplied in your Hewlett-Packard Oscilloscope and replacement cathode ray tubes purchased from ℌ, are guaranteed against electrical failure for one year from the date of sale by the Hewlett-Packard Company. Broken tubes or tubes with burned phosphor are not included in this guarantee.

Your local Hewlett-Packard representative maintains a stock of replacement tubes and will be glad to process your warranty claim for you. Please consult him.

Whenever a tube is returned for a warranty claim, the reverse side of this sheet must be filled out in full and returned with the tube. Follow shipping instructions carefully to insure safe arrival, since no credit can be allowed on broken tubes.

SHIPPING INSTRUCTIONS

1) Carefully wrap the tube in 1/4" thick cotton batting or other soft padding material.

2) Wrap the above in heavy kraft paper.

3) Pack in a rigid container which is at least 4 inches larger than the tube in each dimension.

4) Surround the tube with at least four inches of packed excelsior or similar shock absorbing material. Be certain that the packing is tight all around the tube.

5) Tubes returned from outside the continental United States should be packed in a wooden box.

6) Ship prepaid preferably by AIR FREIGHT or RAILWAY EXPRESS. We do not recommend parcel post or air parcel post shipment.

HEWLETT-PACKARD CO. PAGE MILL ROAD, PALO ALTO, CALIF. U.S.A.

CRT WARRANTY CLAIM

FROM: DATE: _____

NAME: _____

COMPANY: _____

ADDRESS: _____

_____

_____

Person to contact for further information:

NAME: _____

TITLE: _____

COMPANY: _____

ADDRESS: _____

_____

_____

To process your claim quickly please enter the information indicated below:

1) ℗ INSTRUMENT MODEL _____ SERIAL _____

2) TUBE TYPE _____ SERIAL _____

3) ORIGINAL TUBE _____ REPLACEMENT TUBE _____

4) YOUR PURCHASE ORDER NO. _____

5) DATE PURCHASED _____

6) PURCHASED FROM _____

7) COMPLAINT: (Please describe nature of trouble) _____

_____

_____

_____

8) OPERATING CONDITIONS: (Please describe conditions prior to and at time of failure _____

_____

_____

_____

SIGNATURE _____

_____

LIST OF MANUFACTURERS

The following code numbers are from the Federal Supply Code for Manufacturers Cataloging Handbooks H4-1 (Name to Code) and H4-2 (Code to Name) and their latest supplements. The date of revision and the date of the supplements used appear at the bottom of each page. Alphabetical codes have been arbitrarily assigned to suppliers not appearing in the H4 handbooks.

CODE NO.	MANUFACTURER	ADDRESS
00334	Humidial Co.	Colton, Calif.
00335	Westrex Corp.	New York, N.Y.
00656	Aerovox Corp.	New Bedford, Mass.
00781	Aircraft Radio Corp.	Boonton, N.J.
00853	Sangamo Electric Co., Cap. Div.	Marion, Ill.
00891	Carl E. Holmes Corp.	Los Angeles, Calif.
01121	Allen Bradley Co.	Milwaukee, Wis.
01255	Litton Industries, Inc.	Beverly Hills, Calif.
01281	Pacific Semiconductors, Inc.	Culver City, Calif.
01295	Texas Instruments, Inc. Semiconductor Components Div.	Dallas, Texas
01349	The Alliance Mfg. Co.	Alliance, Ohio
02114	Ferroxcube Corp. of America	Saugerties, N.Y.
02286	Cole Mfg. Co.	Palo Alto, Calif.
02660	Amphenol Electronics Corp.	Chicago, Ill.
02735	Radio Corp. of America Semiconductor and Materials Div.	Somerville, N.J.
02777	Hopkins Engineering Co.	San Francisco, Calif.
03508	G.E. Semiconductor Products Dept.	Syracuse, N.Y.
03705	Apex Machine & Tool Co.	Dayton, Ohio
03797	Eldema Corp.	El Monte, Calif.
04009	Arrow, Hart and Hegeman Elect. Co.	Hartford, Conn.
04222	Hi-Q Division of Aerovox	Myrtle Beach, S.C.
04404	Dymec Inc.	Palo Alto, Calif.
04651	Special Tube Operations of Sylvania Electronic Systems	Mountain View, Calif.
04713	Motorola, Inc., Semiconductor Prod. Div.	Phoenix, Arizona
04777	Automatic Electric Sales Corp.	Northlake, Ill.
05624	Barber Colman Co.	Rockford, Ill.
05783	Stewart Engineering Co.	Soquel, Calif.
06004	The Bassick Co.	Bridgeport, Conn.
06812	Torrington Mfg. Co., West. Div.	Van Nuys, Calif.
07115	Corning Glass Works Electronic Components Dept.	Bradford, Pa.
07261	Avnet Corp.	Los Angeles, Calif.
07263	Fairchild Semiconductor Corp.	Mountain View, Calif.
07933	Rheem Semiconductor Corp.	Mountain View, Calif.
07980	Boonton Radio Corp.	Boonton, N.J.
08718	Cannon Electric Co. Phoenix Div.	Phoenix, Ariz.
08733	Camloc Fastener Corp.	Los Angeles, Calif.
08792	CBS Electronics Semiconductor Operations, Div. of C.B.S. Inc.	Lowell, Mass.
09134	Texas Capacitor Co.	Houston, Texas
09250	Electro Assemblies, Inc.	Chicago, Ill.
10646	Carborundum Co.	Niagara Falls, N.Y.
12697	Clarostat Mfg. Co.	Dover, N.H.
14655	Cornell Dubilier Elec. Corp.	So. Plainfield, N.J.
15909	The Daven Co.	Livingston, N.J.
16758	Delco Radio Div. of G. M. Corp.	Kokomo, Ind.
18873	E. I. DuPont and Co., Inc.	Wilmington, Del.
19315	Eclipse Pioneer, Div. of Bendix Aviation Corp.	Teterboro, N.J.
19500	Thomas A. Edison Industries, Div. of McGraw-Edison Co.	West Orange, N.J.
19701	Electra Manufacturing Co.	Kansas City, Mo.
20183	Electronic Tube Corp.	Philadelphia, Pa.
21520	Fansteel Metallurgical Corp.	No. Chicago, Ill.
21335	The Fafnir Bearing Co.	New Britain, Conn.
21964	Fed. Telephone and Radio Corp.	Clifton, N.J.
24446	General Electric Co.	Schenectady, N.Y.
24455	G. E., Lamp Division	Nela Park, Cleveland, Ohio
24655	General Radio Co.	West Concord, Mass.
26462	Grobet File Co. of America, Inc.	Carlstadt, N.J.
26992	Hamilton Watch Co.	Lancaster, Pa.
28480	Hewlett-Packard Co.	Palo Alto, Calif.
33173	G. E. Receiving Tube Dept.	Owensboro, Ky.
35434	Lectrohm Inc.	Chicago, Ill.
37942	P. R. Mallory & Co., Inc.	Indianapolis, Ind.
39543	Mechanical Industries Prod. Co.	Akron, Ohio
40920	Miniature Precision Bearings, Inc.	Keene, N.H.
42190	Muter Co.	Chicago, Ill.
44655	Ohmite Mfg. Co.	Skokie, Ill.
48620	Precision Thermometer and Inst. Co.	Philadelphia, Pa.
54294	Shallcross Mfg. Co.	Selma, N.C.
55933	Sonotone Corp.	Elmsford, N.Y.
55938	Sorenson & Co., Inc.	So. Norwalk, Conn.
56137	Spaulding Fibre Co., Inc.	Tonawanda, N.Y.
56289	Sprague Electric Co.	North Adams, Mass.
61775	Union Switch and Signal, Div. of Westinghouse Air Brake Co.	Pittsburgh, Pa.
62119	Universal Electric Co.	Owosso, Mich.
64959	Western Electric Co., Inc.	New York, N.Y.
65092	Weston Inst. Div. of Daystrom, Inc.	Newark, N.J.
70119	Advance Electric and Relay Co.	Burbank, Calif.
70276	Allen Mfg. Co.	Hartford, Conn.
70309	Allied Control Co., Inc.	New York, N.Y.
70563	Amperite Co., Inc	New York, N.Y.
70903	Belden Mfg. Co.	Chicago, Ill.
70998	Bird Electronic Corp.	Cleveland, Ohio
71002	Birnbach Radio Co.	New York, N.Y.
71218	Bud Radio Inc.	Cleveland, Ohio
71286	Camloc Fastener Corp.	Paramus, N.J.
71313	Allen D. Cardwell Electronic Prod. Corp	Plainville, Conn.
71400	Bussmann Fuse Div. of McGraw-Edison Co.	St. Louis, Mo.
71450	Chicago Telephone Supply Co.	Elkhart, Ind.
71468	Cannon Electric Co.	Los Angeles, Calif.
71471	Cinema Engineering Co.	Burbank, Calif.
71482	C. P. Clare & Co.	Chicago, Ill.
71590	Centralab Div. of Globe Union Inc.	Milwaukee, Wis.
71700	The Cornish Wire Co.	New York, N.Y.
71744	Chicago Miniature Lamp Works	Chicago, Ill.
71753	A. O. Smith Corp., Crowley Div.	West Orange, N.J.
71785	Cinch Mfg. Corp.	Chicago, Ill.
71984	Dow Corning Corp.	Midland, Mich.
72136	Electro Motive Mfg. Co., Inc.	Willimantic, Conn.
72619	Dialight Corp.	Brooklyn, N.Y.
72656	General Ceramics Corp.	Keasbey, N.J.
72758	Girard-Hopkins	Oakland, Calif.
72765	Drake Mfg. Co.	Chicago, Ill.
72825	Hugh H. Eby Inc.	Philadelphia, Pa.
72928	Gudeman Co.	Chicago, Ill.
72982	Erie Resistor Corp.	Erie, Pa.
73061	Hansen Mfg. Co., Inc.	Princeton, Ind.
73138	Helipot Div. of Beckman Instruments, Inc.	Fullerton, Calif.
73293	Hughes Products Div. of Hughes Aircraft Co.	Newport Beach, Calif.
73445	Amperex Electronic Co., Div. of North American Phillips Co., Inc.	Hicksville, N.Y.
73506	Bradley Semiconductor Corp.	New Haven, Conn.
73559	Carling Electric, Inc.	Hartford, Conn.
73682	George K. Garrett Co., Inc.	Philadelphia, Pa.
73743	Fischer Special Mfg. Co.	Cincinnati, Ohio
73793	The General Industries Co.	Elyria, Ohio
73905	Jennings Radio Mfg. Co.	San Jose, Calif.
74455	J. H. Winns, and Sons	Winchester, Mass.
74861	Industrial Condenser Corp.	Chicago, Ill.
74868	Industrial Products Co.	Danbury, Conn.
74970	E. F. Johnson Co.	Waseca, Minn.
75042	International Resistance Co.	Philadelphia, Pa.
75378	James Knights Co.	Sandwich, Ill.
75382	Kulka Electric Mfg. Co., Inc.	Mt. Vernon, N.Y.
75818	Lenz Electric Mfg. Co.	Chicago, Ill.
75915	Littlefuse Inc.	Des Plaines, Ill.
76005	Lord Mfg. Co.	Erie, Pa.
76210	C. W. Marwedel	San Francisco, Calif.
76433	Micamold Electronic Mfg. Corp.	Brooklyn, N.Y.
76487	James Millen Mfg. Co., Inc.	Malden, Mass.
76530	Monadnock Mills	San Leandro, Calif.
76545	Mueller Electric Co.	Cleveland, Ohio
76854	Oak Manufacturing Co.	Chicago, Ill.
77068	Bendix Corp., Bendix Pacific Div.	No. Hollywood, Calif.
77221	Phaostron Instrument and Electronic Co.	South Pasadena, Calif.
77342	Potter and Brumfield, Inc.	Princeton, Ind.
77630	Radio Condenser Co.	Camden, N.J.
77634	Radio Essentials Inc.	Mt. Vernon, N.Y.
77638	Radio Receptor Co., Inc.	Brooklyn, N.Y.
77764	Resistance Products Co.	Harrisburg, Pa.
78283	Signal Indicator Corp.	New York, N.Y.
78471	Tilley Mfg. Co.	San Francisco, Calif.
78488	Stackpole Carbon Co.	St. Marys, Pa.
79142	Veeder Root, Inc.	Hartford, Conn.
79251	Wenco Mfg. Co.	Chicago, Ill.
79963	Zierick Mfg. Corp.	New Rochelle N.Y.
80130	Times Facsimile Corp.	New York, N.Y.
80248	Oxford Electric Corp.	Chicago, Ill.
80411	Acro Manufacturing Co.	Columbus, Ohio
80486	All Star Products Inc.	Defiance, Ohio
80583	Hammerlund Co., Inc.	New York, N.Y.
80640	Stevens, Arnold, Co., Inc.	Boston, Mass.
81030	International Instruments, Inc.	New Haven, Conn.
81415	Wilkor Products, Inc.	Cleveland, Ohio
81453	Raytheon Mfg. Co., Industrial Tube Division	Quincy, Mass.

From: F.S.C. Handbook Supplements
H4-1 Dated July 1960
H4-2 Dated July 1960

LIST OF MANUFACTURERS

CONTINUED

CODE NO.	MANUFACTURER	ADDRESS
81483	International Rectifier Corp.	El Segundo, Calif.
82042	Carter Parts Co.	Skokie, Ill.
82170	Allen B. DuMont Labs., Inc.	Clifton, N.J.
82209	Maguire Industries, Inc.	Greenwich, Conn.
82219	Sylvania Electric Prod. Inc., Electronic Tube Div.	Emporium, Pa.
82376	Astron Co.	East Newark, N.J.
82389	Switchcraft, Inc.	Chicago, Ill.
82647	Spencer Thermostat, Div. of Texas Instruments, Inc.	Attleboro, Mass.
82866	Research Products Corp.	Madison, Wis.
82893	Vector Electronic Co.	Glendale, Calif.
83148	Electro Cords Co.	Los Angeles, Calif.
83186	Victory Engineering Corp.	Union, N.J.
83298	Bendix Corp., Red Bank Div.	Red Bank, N.J.
83594	Burroughs Corp., Electronic Tube Div.	Plainfield, N.J.
83777	Model Eng. and Mfg., Inc.	Huntington, Ind.
83821	Loyd Scruggs Co.	Festus, Mo.
84171	Arco Electronics, Inc.	New York, N.Y.
84396	A. J. Glesener Co., Inc.	San Francisco, Calif.
84411	Good All Electric Mfg. Co.	Ogallala, Neb.
84970	Sarkes Tarzian, Inc.	Bloomington, Ind.
85474	R. M. Bracamonte & Co.	San Francisco, Calif.
85660	Koiled Kords, Inc.	New Haven, Conn.
86684	Radio Corp. of America, RCA Electron Tube Div.	Harrison, N.J.
88140	Cutler-Hammer, Inc.	Lincoln, Ill.
89473	General Electric Distributing Corp.	Schenectady, N.Y.
90179	U.S. Rubber Co., Mechanical Goods Div.	Passaic, N.J.
90970	Bearing Engineering Co.	San Francisco, Calif.
91418	Radio Materials Co.	Chicago, Ill.
91506	Augat Brothers, Inc.	Attleboro, Mass.
91637	Dale Products, Inc.	Columbus, Neb.
91662	Elco Corp.	Philadelphia, Pa.
91737	Gremar Mfg. Co., Inc.	Wakefield, Mass.
91929	Micro-Switch Div. of Minneapolis Honeywell Regulator Co.	Freeport, Ill.
93332	Sylvania Electric Prod. Inc., Semiconductor Div.	Woburn, Mass.
93410	Stevens Mfg. Co., Inc.	Mansfield, Ohio
93983	Insuline-Van Norman Ind., Inc. Electronic Division	Manchester, N.H.
94144	Raytheon Mfg. Co., Receiving Tube Div.	Quincy, Mass.
94145	Raytheon Mfg. Co., Semiconductor Div.	Newton, Mass.
94154	Tung-Sol Electric, Inc.	Newark, N.J.
94197	Curtiss-Wright Corp., Electronics Div.	Carlstadt, N.J.
94310	Tru Ohm Prod. Div. of Model Engineering and Mfg. Co.	Chicago, Ill.
95236	Allies Products Corp.	Miami, Fla.
95238	Continental Connector Corp.	Woodside, N.Y.
95263	Leecraft Mfg. Co., Inc.	New York, N.Y.
95265	National Coil Co.	Sheridan, Wyo.
95987	Weckesser Co.	Chicago, Ill.
96067	Huggins Laboratories	Sunnyvale, Calif.
96095	Hi-Q Division of Aerovox	Olean, N.Y.
96296	Solar Manufacturing Co.	Los Angeles, Calif.
96341	Microwave Associates, Inc.	Burlington, Mass.
96501	Excel Transformer Co.	Oakland, Calif.
97539	Automatic and Precision Mfg. Co.	Yonkers, N.Y.
97966	CBS Electronics, Div. of C.B.S., Inc.	Danvers, Mass.
98141	Axel Brothers Inc.	Jamaica, N.Y.
98220	Francis L. Mosley	Pasadena, Calif.
98291	Sealectro Corp.	New Rochelle, N.Y.
98405	Carad Corp.	Redwood City, Calif.
98734	Palo Alto Engineering Co., Inc.	Palo Alto, Calif.
98925	Clevite Transistor Prod. Div. of Clevite Corp.	Waltham, Mass.
99313	Varian Associates	Palo Alto, Calif.
99800	Delevan Electronics Corp.	East Aurora, N.Y.
99848	Wilco Corporation	Indianapolis, Ind.
99934	Renbrandt, Inc.	Boston, Mass.
99957	Technology Instruments Corp. of Calif.	No. Hollywood, Calif.

THE FOLLOWING H-P VENDORS HAVE NO NUMBER ASSIGNED IN THE LATEST SUPPLEMENT TO THE FEDERAL SUPPLY CODE FOR MANUFACTURERS HANDBOOK.

0000A	Amp, Inc.	Hawthorne, Calif.
0000B	Chicago Telephone of Calif.	S. Pasadena, Calif
0000C	Connor Spring Mfg. Co.	San Francisco, Calif.
0000D	Connex Corp.	Oakland, Calif.
0000E	Fisher Switches, Inc.	San Francisco, Calif.
0000F	Malco Tool and Die	Los Angeles, Calif.
0000G	Microwave Engineering Co.	Palo Alto, Calif.
0000H	Philco Corp. (Lansdale Tube Division)	Lansdale, Pa.
0000I	Telefunken (c/o American Elite)	New York, N.Y.
0000J	Ti Tal, Inc.	Berkeley, Calif.
0000K	Transitron Electronic Sales Corp.	Wakefield, Mass.
0000L	Winchester Electronics, Inc.	Santa Monica, Calif.
0000M	Western Coil Div. of Automatic Ind., Inc.	Redwood City, Calif.
0000N	Nahm-Bros. Spring Co.	San Leandro, Calif.
0000P	Ty-Car Mfg. Co., Inc.	Holliston, Mass.

From: F.S.C. Handbook Supplements
H4-1 Dated July 1960
H4-2 Dated July 1960

ELECTRONIC

SALES & SERVICE OFFICES

UNITED STATES

ALABAMA
P.O. Box 4207
2003 Byrd Spring Road S.W.
Huntsville 35802
Tel: (205) 881-4591
TWX: 810-726-2204

ARIZONA
2336 E. Magnolia St.
Phoenix 85034
Tel: (602) 252-5061
TWX: 910-951-1330

5737 East Broadway
Tucson 85716
Tel: (602) 298-2313
TWX: 910-952-1162

CALIFORNIA
1430 East Orangethorpe Ave.
Fullerton 92631
Tel: (714) 870-1000

3939 Lankershim Boulevard
North Hollywood 91604
Tel: (213) 877-1282
TWX: 910-499-2170

1101 Embarcadero Road
Palo Alto 94303
Tel: (415) 327-6500
TWX: 910-373-1280

2220 Watt Ave.
Sacramento 95825
Tel: (916) 482-1463
TWX: 910-367-2092

9606 Aero Drive
San Diego 92123
Tel: (714) 279-3200
TWX: 910-335-2000

COLORADO
7965 East Prentice
Englewood 80110
Tel: (303) 771-3455
TWX: 910-935-0705

CONNECTICUT
508 Tolland Street
East Hartford 06108
Tel: (203) 289-9394
TWX: 710-425-3416

111 East Avenue
Norwalk 06851
Tel: (203) 853-1251
TWX: 710-468-3750

FLORIDA
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Atlanta 30328
Tel: (404) 436-6181
TWX: 810-766-4890

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TWX: 910-223-3613

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Indianapolis 46205
Tel: (317) 546-4891
TWX: 810-341-3263

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Tel: (301) 948-6370
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Tel: (617) 861-8960
TWX: 710-326-6904

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Southfield 48075
Tel: (313) 353-9100
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Tel: (612) 645-9461
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Tel: (816) 763-8000
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St. Louis 63144
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NEW MEXICO
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Station C
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Columbus 43229
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Oklahoma City 73112
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TWX: 910-830-6862

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4475 S.W. Scholls Ferry Road
Portland 97225
Tel: (503) 292-9171
TWX: 910-464-6103

PENNSYLVANIA
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Monroeville 15146
Tel: (412) 271-0724
TWX: 710-797-3650

1021 8th Avenue
King of Prussia Industrial Park
King of Prussia 19406
Tel: (215) 265-7000
TWX: 510-660-2670

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East Providence 02914
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TWX: 710-381-7573

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Houston 77027
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Kennedy Drive
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Tel: (802) 658-4455
TWX: 510-299-0025

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2111 Spencer Road
Richmond 23230
Tel: (703) 285-3431
TWX: 710-956-0157

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433-108th N.E.
Bellevue 98004
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TWX: 910-443-2303

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Charleston
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Edmonton
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Hewlett-Packard (Canada) Ltd.
4519 Canada Way
North Burnaby 2
Tel: (604) 433-8213
TWX: 610-922-5059

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Hewlett-Packard (Canada) Ltd.
511 Bradford Ct.
Winnipeg
Tel: (204) 786-7581
TWX: 610-671-3531

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2745 Dutch Village Rd.
Suite 206
Halifax
Tel: (902) 455-0511
TWX: 610-271-4482

ONTARIO
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880 Lady Ellen Place
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50 Galaxy Blvd.
Rexdale
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TWX: 610-492-4246

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TWX: 610-422-3022
Telex: 01-20607

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CENTRAL AND SOUTH AMERICA

ARGENTINA
Hewlett-Packard Argentina S.A.C.e.I
Lavalle 1171 - 3°
Buenos Aires
Tel: 35-0436, 35-0627, 35-0431
Telex: 012-1009
Cable: HEWPACKARG

BRAZIL
Hewlett-Packard Do Brasil I.e.C Ltda.
Rua Frei Caneca 1119
Sao Paulo - 3, SP
Tel: 288-7111, 287-5858
Cable: HEWPACK Sao Paulo

Hewlett-Packard Do Brasil
Praca Dom Feliciano 78
Salas 806/808
Porto Alegre
Rio Grande do Sul (RS)-Brasil
Tel: 25-8470
Cable: HEWPACK Porto Alegre

Hewlett-Packard Do Brasil I.e.C. Ltda.
Rua da Matriz 29
Botafogo ZC-02
Rio de Janeiro, GB
Tel: 246-4417
Cable: HEWPACK Rio de Janeiro

CHILE
Héctor Calcagni y Cia, Ltda.
Bustos, 1932-3er Piso
Casilla 13942
Santiago
Tel: 423 96
Cable: CALCAGNI Santiago

COLOMBIA
Instrumentacion
Henrik A. Langebaek & Kier Ltda.
Carrera 7 No. 48-59
Apartado Aereo 6287
Bogota, 1 D.E.
Tel: 45-78-06, 45-55-46
Cable: AARIS Bogota
Telex: 44400 INSTCO

COSTA RICA
Lic. Alfredo Gallegos Gurdián
Apartado 10159
San José
Tel: 21-86-13
Cable: GALGUR San José

ECUADOR
Laboratorios de Radio-Ingenieria
Calle Guayaquil 1246
Post Office Box 3199
Quito
Tel: 212-496; 219-185
Cable: HORVATH Quito

EL SALVADOR
Electronic Associates
Apartado Postal 1682
Centro Comercial Gigante
San Salvador, El Salvador
Paseo Escalon 4649-4th Piso
Tel: 23-44-60, 23-32-37
Cable: ELECAS

MEXICO
Hewlett-Packard Mexicana, S.A. de C.V.
622 Adolfo Prieto
Col. del Valle
Mexico 12, D.F.
Tel: 543-4232; 523-1874
Telex: 0017-74507

NICARAGUA
Roberto Terán G.
Apartado Postal 689
Edificio Terán
Managua
Tel: 3451, 3452
Cable: ROTERAN Managua

PANAMA
Electrónico Balboa, S.A.
P.O. Box 4929
Ave. Manuel Espinosa No. 13-50
Bldg. Alina
Panama City
Tel: 230833
Telex: 3481003, Curundu, Canal Zone
Cable: ELECTRON Panama City

PARAGUAY
Z.T. Melamed S.R.L.
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Salon de Exposicion y Escritorio:
Chile 482
Edificio Victoria—Planta Baja
Asuncion, Paraguay
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Ave. Enrique Canaual 312
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Casilla 1030
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Tel: 22-3900
Cable: ELMED Lima

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San Juan Electronics, Inc.
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Pda. 3-PTA de Tierra
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Cable: SATRONICS San Juan
Telex: SATRON 3450 332

SURINAME
Surtel-Radio Holland N.V.
P.O. Box 155
Paramaribo
Tel: 72118
Cable: Treurniet Paramaribo

URUGUAY
Pablo Ferrando S.A.
Comercial e Industrial
Avenida Italia 2877
Casilla de Correo 370
Montevideo
Tel: 40-3102
Cable: RADIUM Montevideo

VENEZUELA
Hewlett-Packard De Venezuela C.A.
Apartado 50933
Caracas
Tel: 71.88.05, 71.88.69, 71.99.30
Cable: HEWPACK Caracas
Telex: 39521146

FOR AREAS NOT LISTED,

CONTACT:
Hewlett-Packard
INTERCONTINENTAL
3200 Hillview Ave.
Palo Alto, California 94304
Tel: (415) 493-1501
TWX: 910-373-1267
Cable: HEWPACK Palo Alto
Telex: 034-8461

EUROPE

AUSTRIA
Hewlett-Packard Ges.m.b.H
Innstrasse 23/2
Postfach 45
A-1204 **Vienna**
Tel: (0222) 33 66 06-09
Cable: HEWPAK Vienna
Telex: 75923 hewpak a

BELGIUM
Hewlett-Packard Benelux
S.A./N.V.
Avenue du Col-Vert, 1
B-1170 **Brussels**
Tel: (02) 72 22 40
Cable: PALOBEN Brussels
Telex: 23 494

DENMARK
Hewlett-Packard A/S
Datavej 38
DK-3460 **Birkerod**
Tel: (01) 81 66 40
Cable: HEWPACK AS
Telex: 16640 hp as

Hewlett-Packard A/S
Torvet 9
DK-8600 **Silkeborg**
Tel: (06)-82-71-66
Telex: 16640 hp as
Cable: HEWPACKAS

FINLAND
Hewlett-Packard Oy
Bulevardi 26
P.O. Box 12185
SF-00120 **Helsinki 12**
Tel: 13-730
Cable: HEWPACKOY-Helsinki
Telex: 12-1563

FRANCE
Hewlett-Packard France
Quartier de Courtaboeuf
Boite Postale No. 6
F-91 **Orsay**
Tel: (1) 907 78 25
Cable: HEWPACK Orsay
Telex: 60048

Hewlett-Packard France
4 Quai des Etroits
F-69 **Lyon 5ème**
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Telex: 31617

Hewlett-Packard France
29 rue de la Gare
F-31 **Blagnac**
Tel: (61) 85 82 29
Telex: 51957

GERMAN FEDERAL REPUBLIC
Hewlett-Packard Vertriebs-GmbH
Berliner Strasse 117
Postfach 560/40
D-6 **Nieder-Eschbach/Ffm 56**
Tel: (0611) 50-04-1
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Telex: 41 32 49 FRA

Hewlett-Packard Vertriebs-GmbH
Herrenbergerstrasse 110
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Tel: (07031) 66 72 86
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D-4 **Düsseldorf**
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Telex: 85/86 533

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Unterhachinger Strasse 28
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(West Berlin)
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Wilmersdorfer Strasse 113/114
D-1000 **Berlin W.** 12
Tel: (0311) 3137046
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18, Ermou Street
Athens 126
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Cable: RAKAR Athens
Telex: 21 59 62 **RKAR GR**

IRELAND
Hewlett-Packard Ltd.
224 Bath Road
Slough, SL1 4 DS, Bucks
Tel: Slough 753-33341
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Telex: 84413

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S.A./N.V.
Avenue du Col-Vert, 1
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Telex: 23 494

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Amsterdam, Z 11
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N-1344 **Haslum**
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Enighetsvägen 1-3
Fack
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Tel: (08) 98 12 50
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S-431 41 **Mölndal**
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Zürcherstrasse 20
CH-8952 **Schlieren** Zurich
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Telex: 53933

Hewlett-Packard (Schweiz) AG
Rue du Bois-du-Lan 7
P.O. Box 85
1217 Meyrin 2 Geneva
Tel: (022) 41 54 00
Cable: HEWPACKSA Geneva
Telex: 27333 HPSA CH

TURKEY
Telekom Engineering Bureau
P.O. Box 376
Karaköy
Istanbul
Tel: 49 40 40
Cable: TELEMATION Istanbul

UNITED KINGDOM
Hewlett-Packard Ltd.
224 Bath Road
Slough, SL1 4 DS, Bucks
Tel: Slough (0753) 33341
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Telex: 84413

Hewlett-Packard Ltd.
"The Graftons"
Stamford New Road
Altrincham, Cheshire
Tel: (061) 928-8626
Telex: 668068

YUGOSLAVIA
Belram S.A.
83 avenue des Mimosas
Brussels 1150, Belgium
Tel: 34 33 32, 34 26 19
Cable: BELRAMEL Brussels
Telex: 21790

SOCIALIST COUNTRIES PLEASE CONTACT:
Hewlett-Packard Ges.m.b.H
Innstrasse 23/2
Postfach 45
A-1204 **Vienna**, Austria
Tel: (0222) 33 66 06-09
Cable: HEWPACK Vienna
Telex: 75923 hewpak a

ALL OTHER EUROPEAN COUNTRIES CONTACT:
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Switzerland
Tel: (022) 41 54 00
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Telex: 2.24.86

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Telectra Empresa Técnia
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42-1°
Box 6487
Luanda
Cable: TELECTRA Luanda

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Victoria
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Telex: 31024

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New South Wales
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Telex: 21561

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South Australia
Tel: 65.2366
Cable: HEWPARD Adelaide

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2nd Floor, Suite 13
Casablanca Buildings
196 Adelaide Terrace
Perth, W.A. 6000
Tel: 21-3330
Cable: HEWPARD Perth

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Pty. Ltd.
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P.O. Box 191
Dickson A.C.T. 2602
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Cable: HEWPARD Canberra ACT

Hewlett-Packard Australia
Pty. Ltd.
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Tel: 78 6069

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Yahala Building
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Addis Ababa
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Telex: 2156
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Bangalore-8

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Dindli Road
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Bandung
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Cable: ILMU
Telex: 08-809

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Teheran
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Cable: BASCOM Teheran
Telex: 2664

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Div. of Motorola Israel Ltd.
17 Aminadav Street
Tel-Aviv
Tel: 36941 (3 lines)
Cable: BASTEL Tel-Aviv
Telex: Bastel Tv 033-569

JAPAN
Yokogawa-Hewlett-Packard Ltd.
Ohashi Building
1-59-1 Yoyogi
Shibuya-ku, Tokyo
Tel: 03-370-2281/7
Telex: 232-2024YHP
Cable: YHPMARKET TOK 23-724

Yokogawa-Hewlett-Packard Ltd.
Nisei Ibaragi Bldg.
2-2-8 Kasuga
Ibaragi-Shi
Osaka
Tel: (0726) 23-1641
Telex: 385-5332 YHPOSAKA

Yokogawa-Hewlett-Packard Ltd.
Ito Building
No. 59, Kotori-cho
Nakamura-ku, Nagoya City
Tel: (052) 551-0215

Yokogawa-Hewlett-Packard Ltd.
Nitto Bldg.
2300 Shinohara-cho,
Kohoku-ku
Yokohama 222
Tel: (405) 432-1504/5

JORDAN
Constantin E. Macridis
Clemenceau Street
P.O. Box 7213
Beirut, Lebanon
Tel: 220846
Cable: ELECTRONUCLEAR Beirut

KENYA
Kenya Kinetics
P.O. Box 18311
Nairobi, Kenya
Tel: 57726
Cable: PROTON

KOREA
American Trading Co.,
Korea, Ltd.
Seoul P.O. Box 1103
7th & 8th floors, DaeKyung Bldg.
107 Sejong Ro
Chongro-Ku, Seoul
Tel: 75-5841 (4 lines)
Cable: AMTRACO Seoul

LEBANON
Constantin E. Macridis
Clemenceau Street
P.O. Box 7213
Beirut
Tel: 220846
Cable: ELECTRONUCLEAR Beirut

MALAYSIA
MECOMB Malaysia Ltd.
2 Lorong 13/6A
Section 13
Petaling Jaya, **Selangor**
Cable: MECOMB Kuala Lumpur

MOZAMBIQUE
A. N. Goncalves, LDA.
4.1 Apt. 14 Av. D. Luis
P.O. Box 107
Lourenco Marques
Cable: NEGON

NEW ZEALAND
Hewlett-Packard (N.Z.) Ltd.
94-96 Dixson St.
P.O. Box 9443
Wellington, N.Z.
Tel: 56-559
Cable: HEWPACK Wellington

Hewlett Packard (N.Z.) Ltd.
Box 51092
Pukuranga
Tel: 569-651
Cable: HEWPACK, Auckland

PAKISTAN (EAST)
Mushko & Company, Ltd.
1, Jinnah Avenue
Dacca 2
Tel: 280058
Cable: NEWDEAL Dacca

PAKISTAN (WEST)
Mushko & Company, Ltd.
Oosman Chambers
Abdullah Haroon Road
Karachi 3
Tel: 511027, 512927
Cable: COOPERATOR Karachi

Mushko & Company, Ltd.
38B, Satellite Town
Rawalpindi
Tel: 41924
Cable: FEMUS Rawalpindi

PHILIPPINES
Electromex Inc.
5th Floor, Architects
Center Bldg.
Ayala Ave., Makati, Rizal
C.C.P.O. Box 1028
Makati, Rizal
Tel: 86-18-87, 87-76-77
Cable: ELEMEX Manila

SINGAPORE
Mechanical and Combustion
Engineering Company Ltd.
9, Jalan Kilang
Red Hill Industrial Estate
Singapore, 3
Tel: 642361-3; 632611
Cable: MECOMB Singapore

Hewlett-Packard Far East
Area Office
P.O. Box 87
Alexandra Post Office
Singapore 3
Tel: 633022
Cable: HEWPACK SINGAPORE

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Milnerton
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Johannesburg
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Telex: 0226 JH
Cable: HEWPACK Johannesburg

Hewlett Packard South Africa
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Breecastle House
Bree Street
Cape Town
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Cable: HEWPACK Cape Town
Telex: 5-0006

Hewlett Packard South Africa
(Pty.), Ltd.
641 Ridge Road, Durban
P.O. Box 99
Overport, Natal
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Telex: 567954
Cable: HEWPACK

TAIWAN
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Sec. 1
Overseas Insurance
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Taipei
Tel: 389160,1,2, 375121,
Ext. 240
Telex: TP824 HEWPACK
Cable: HEWPACK Taipei

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MEDITERRANEAN AND MIDDLE EAST COUNTRIES NOT SHOWN PLEASE CONTACT:
Hewlett-Packard
Co-ordination Office for
Mediterranean and Middle
East Operations
Via Marocco, 7
I-00144 Rome-Eur, Italy
Tel: (6) 59 40 29
Cable: HEWPACKIT Rome
Telex: 61514

OTHER AREAS NOT LISTED, CONTACT:
Hewlett-Packard
INTERCONTINENTAL
3200 Hillview Ave.
Palo Alto, California 94304
Tel: (415) 326-7000
(Feb. 71 493-1501)
TWX: 910-373-1267
Cable: HEWPACK Palo Alto
Telex: 034-8461

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